DEPARTMENT OF ENGINEERING OF THE U. S. ARTILLERY SCHOOL.

COURSE ON

MILITARY COMMUNICATIONS,

PART I.

MILITARY BRIDGES.

— BY —

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Approved and authorized as a Text Book. —

Par. 26, *Regulations U. S. Artillery School, Approved*, 1882, *viz*:—

"To the end that the school shall keep pace with professional progress, it is made the duty of "Instructors and Assistant Instructors to prepare and arrange in accordance with the Programme "of Instruction, the subject-matter of the courses of study committed to their charge. The same "shall be submitted to the Staff, and, after approval by that body, the matter shall become the "authorized text-books of the school, be printed at the school, issued, and adhered to as such."

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By order of
BREVET MAJOR GENERAL GETTY:

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1st Lieutenant 3rd Artillery, A. D. C.,
Adjutant and Secretary of the Staff.

PREFACE.

The time which can be spared for the Course on Military Bridges precludes any exhaustive treatment of the subject. In the following papers the bridges described have been selected on account of their simplicity and adaptability. They are such as any army officer may be called upon to build in the course of his service, under the most disadvantageous circumstances, and in the least possible time. A thorough knowledge of their construction, in all its details, is therefore indispensible.

The absence of cuts and illustrations is intentional. The officer is expected to study each subject, so as to be able to produce a plan and profile of the bridge, with such illustrations of the methods of construction employed, as he may deem necessary to a clear comprehension of the work. He need not confine himself exclusively to these papers, but may gather information on the subject from every available source.

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INTRODUCTION.

Military Bridges are not required to fulfil all the conditions demanded of an ordinary bridge. They are, as a rule, the creatures of emergency, constructed for a special and immediate purpose, without regard to durability or good looks. The bridge that can be built with unskilled labor, in the shortest time, out of the poorest material, is not unfrequently the one of greatest value to the military commander. How to construct such a bridge, therefore, should constitute part of the education of every army officer.

The utilization of railroads for purposes of war, has increased the importance of this kind of engineering, if it has not created an entirely new branch of the science. Bridges are the most vulnerable part of railroads, and the army operating against an enterprising enemy, and drawing its supplies over such a road, must be prepared, if it would maintain its communications, to rebuild, at a moment's notice, any bridge upon the road.

This necessity during our war of 1861–65 produced a special corps for the construction and operation of Military Railroads, the chief of which for a time — General Hermann Haupt — is the author of the treatise from which the substance of this paper has been drawn.

Such a corps is an absolute necessity to an army campaigning in a civilized country. It assumes all the duties connected with the management and maintenance of railroads, which, the want of special training, unfits our army to perform.

Prominent among such duties is the construction of military railroad bridges. This kind of work properly belongs to such a special corps. Nevertheless, every army officer should have a general idea of the subject; for, although he is not likely

to be called upon to construct such a bridge, he may be called upon, sometime, to destroy one, and a knowledge of its structure will enable him to do so effectually and without waste of time. Besides, no campaign, march, raid, or reconnaissance, can be properly planned, without such a knowledge of bridge construction as will enable the planner to determine the *time value* of every vulnerable bridge upon the route.

The problems in bridge construction which a military engineer is likely to meet in actual war, are very different from those which the civil engineer has to encounter, and his solutions of these problems, when tried by the rules which govern the civil practitioner, frequently appear, not only erroneous, but criminal. In fact, the two branches of engineering have very little in common. The one builds for the present, the other for the future, and the officer who permits himself to be bound by anything but the impossible in bridge construction, has taken a long step towards inefficiency. While the principles and methods of construction should be thoroughly understood, and, as a rule, observed, emergencies will arise when they must be altogether disregarded.

SECTION 1.

The Military Railroad Trestle Bridge.

Military Railroad Bridges are of two kinds — Trestle, and Truss Bridges. Of the two, the Trestle Bridge is the simpler, and, therefore, most resorted to by military engineers. The famous viaduct over Potomac Creek, 400 feet long and 80 feet high, was of this kind. It consisted of three tiers of trestles resting upon crib-work, and was built exclusively of pine logs cut in the vicinity, and worked in without even the bark being removed.

Such a bridge, according to the dicta of the text-books, was little short of a crime ; yet ten or a dozen heavily loaded trains a day passed over it in perfect safety for several months. It was a curiosity in engineering and worthy of careful study. Its character and construction are substantially followed in the following paragraphs.

The simplest and strongest trestle is of the form of an inverted W. It should not exceed 30 feet in height. If the chasm, or river to be bridged, exceeds 30 feet, two tiers of trestles should be resorted to. If it exceeds 60 feet, three tiers.

The Preliminary Work.

The preliminary work to be done by the engineer may be stated as follows : —

1. Make a survey, plan, and section of the river at the point of crossing, and examine the character of the bottom. Note if the stream is liable to freshets, and their height.
2. Examine the available material, its quality, quantity, dimensions, and situation.
3. Plan the trestle.
4. Plan the bridge.
5. Calculate the bill of material required.
6. Calculate the number of officers and men required.
7. Calculate the amount and kind of transportation required.
8. Calculate the quantity and kind of tools required.
9. Calculate the time required for the work.

The Survey should be made with care. The plan should include the approaches on each side, and the section should show the soundings, at intervals sufficiently close to give an accurate outline of the bottom. The water level may be taken as the datum line, and, if the stream be subject to freshets — which its banks will show — the greatest height attained, should be indicated on the section, by a dotted line. The character of the bottom should be carefully noted. It may be rock, or gravel, or hard sand, or mud, or quick-sand. If it be quick-sand, the site must be changed. If it be soft mud, an attempt should be made to ascertain its depth. If the attempt be successful, the depths should be noted on the section. The velocity of the current, and the presence or absence of driftwood should also be noted. In short, everything which can help the engineer towards correct conclusions in determining the character of the structure, should be noted on the plan.

At the close of the survey, the engineer will be able to determine what, if any, foundation will be needed for the trestles. As a rule, on rapid running streams, none will be required. On sluggish streams, with soft muddy bottoms of indefinite depth, crib-work foundations should be resorted to.

The examination of the available material is an important preliminary. Already, the engineer has an idea of the kind of stick required for the contemplated trestle. He must satisfy himself that it exists in sufficient quantity. Round sticks are rated by the diameter of the small end. Anything less than 9″ is too small for trestle-legs. Where the bridge consists of two or three tiers of trestles, the small ends of logs in the lower tiers should match with the large ends of those in the next above; that is, the legs should taper uniformly throughout, provided, always, that the upper end be not less than 9″.

Where timber exists at all in America, it is generally found in sufficient quantity for the purposes of the military engineer, and of a kind that can be used. Pine, perhaps, covers the greatest area, although oak and chestnut are abundant in some parts of the country, and there are places so well stocked that the engineer may select from several varieties.

In the last supposed case, the engineer will not be governed by considerations of strength and durability alone. The element of time in the problem will not permit him to pass by a convenient stick that is *strong enough*, for the purpose of securing an inconvenient one that is *stronger*. Considerations of safety must be sacrificed. in a degree, to the demands of time, and an officer is justified in taking risks in war time, which it would be criminal to assume in times of peace. He will, however, avoid mixing material. If pine be selected for trestle-legs, let them all be pine. Caps, sills, and braces, need not be of the same kind of timber as the legs, although the material for each class should be uniform.

Calculation of the Strength of Beams. — It will rarely be necessary to raise the question of strength of materials in such a shape as to require an appeal to the formulæ of the text-books. The practical engineer recognizes, almost instinctively, the stick that is strong enough for his purpose, but he never can be properly practical without having once been theoretical. He must have studied the strength of materials as he studied the multiplication table, so that, within certain limits, he can apply its teachings readily.

The strains to which bridge timbers are subjected, are those common to all constructions, namely : —

1. Longitudinal Strains.
2. Transverse Strains
3. Strains of Compression.

Longitndinal Strains are resisted by the natural cohesion of the material. The unit of cohesion is measured by the least weight required to rupture a rod one inch square of that material. These units have been determined for the different materials which enter into constructions, and can be found tabulated in any text book of construction, or pocket-book for engineers. The area of the cross-section multiplied by the unit of cohesion found in the table, will give the rupturing weight for the beam, one half of which may be considered the practical load.

Transverse Strains are resisted by the transverse strength of the material. Transverse strength varies directly as the breadth multiplied by the square of the depth, and inversely as the length. The unit of transverse strength for any material being known, the absolute strength of any beam of that material can be calculated, provided the beam is supported and the weight applied in the same way. There are eight variations in the method of support and application, viz : —

1. A beam fixed at one end, and the load applied at the other.
2. A beam fixed at one end, and the load applied uniformly.
3. A beam supported at both ends, and the load applied at the middle.
4. A beam supported at both ends, and the load applied at any point.
5. A beam supported at both ends, and the load distributed uniformly.
6. A beam fixed at both ends, and loaded in the middle.

7. A beam fixed at both ends, and the load applied at any point.

8. A beam fixed at both ends, and the load uniformly distributed.

The unit of transverse strength, S, has been determined for the various materials entering into constructions and can be found tabulated in the text-books or pocket books for engineers. This unit may be affected by any one of the eight conditions above enumerated. To simplify the tables, S is determined for the first case only. For the others, its value is affected by a coefficient as follows: —

Case 1.	Unit of transverse strength			$= S$ to be found in the tables.
" 2.	do	do		$= 2$ S.
" 3.	do	do		$= 4$ S.
" 4.	do	do		$= \dfrac{L^2}{m\,n} S$
" 5.	do	do		$= 8$ S.
" 6.	do	do		$= 9$ S.
" 7.	do	do		$= \dfrac{1\frac{1}{2}L}{m\,n} S$
" 8.	do	do		$= 12$ S.

Where L, m, and n, in the 4th and 7th cases represent, respectively, the length of the beam, the distance of point of application from one end, and the distance of point of application from the other.

The general formula for absolute transverse strength is —

$$W = \frac{bd^2}{L} CS.$$

where

b = breadth of beam.
d = depth of beam.
L = length of beam.
C = coefficient, as above.
S = unit of transverse strength from the table.
W = the weight that will produce rupture, one half of which, as a rule, should be taken as the practical load of the beam.

Strains of Compression are difficult to deal with mathematically, and the strength to resist them depends as much upon the soundness of every part of the stick, as on its dimensions. For square timber the following formula is used.

$$e = \frac{bd^3}{L^2 W}.$$ Where e is the unit of resistance taken from the tables, b, d, and L, the breadth, depth, and length of the stick, and W, the absolute load, half of which should be taken as the practical load.

For round timber, $D = \sqrt[4]{L^2 W \times 1.7\, e}$ Where D = diameter of the log; the other symbols as before.

Planning the Trestles. — If a crib-work foundation is to be resorted to, the irregularities of bottom will thus be overcome and the trestles of the lower tier will be uniform. If not, the lower tier trestles must be planned so as to compensate these irregularities. The strongest and simplest trestle is, as has already been stated, of the form of an inverted W, strengthened, for the lower tiers, by an additional leg in the middle, and braced by plank or poles spiked on the side at the upper and lower ends and in the middle; they should have a batter of from one-eighth to one-tenth their height. The sill is pinned to the bottom of the lower tier trestles, and the cap to the top of the upper ones. When neither sill nor cap is required, three-inch plank are spiked on instead. Plans of the trestles for each tier should be carefully drawn, and pattern trestles constructed.

Planning the Bridge. – A carefully drawn plan and elevation of the bridge, showing, in the plan, the arrangement of the caps and stringers, and, in the elevation, the method of longitudinal bracing, number and position of trestles, low-water and high-water marks, and the road levels at each end of the bridge.

Calculation of Bills of Material. — The bill of material will be calculated as follows: —

Making x = the number of trestles in each tier, which we will suppose are equal.

For lower tier, 5 x Legs, 25′ long and 12″ at small end.
For second tier, 5 x Legs, 25′ long, and 10″ at small end.
For third tier, 4 x Legs, 25′ long, and 9″ at small end.
x Sills, 28′ long and to square 12″.
x Caps, 16′ long and to square 10″.
9 (x + 1.) Longitudinal braces, 13′ long and 4″ at small end.
3 x Trestle braces (Poles) 14′, 18′, and 24′ long, and 4″ at small end.
x " " (3″ plank) 12′ long.
2 x " " (3″ plank) 16′ long.
2 x " " (3″ plank) 20′ long.
x " " (3″ plank) 28′ long.
2 x Cap and sill substitutes (3″ plank) 16′ long.
2 x " " (3″ plank) 23′ long.
2 (x + 1.) Stringers 12′ long and to square 10″ — this assumes six feet as the distance between trestles.

Note. — Spikes, and hard wood pins, 2″ in diameter, or seasoned material to make them, should be procured from the depot.

Note. — The caps, sills, and stringers, should be hewed on the upper and lower sides.

Calculation of the number of men required. — The number of officers and men required for the work includes supernumeraries, cooks, and camp-guards, and should be liberal. Labor, as a rule, is always abundant in armies, and, in American armies, skilled labor sufficiently so to meet all demands for this kind of work.

Before proceeding to determine the number of men required, it is well to review the various operations to be performed. These are —

1. Cutting logs in the woods.
2. Loading and transporting material.
3. Unloading and handling material at the bridge.
4. Framing the trestles.
5. Transporting and raising the trestles.
6. Placing and bracing the trestles.
7. Laying the stringers, and moving the skids.

The strength of parties and number of teams employed, should be such, that material will arrive at the bridge as fast as it is used and no faster. There should be no mixing of material, and no unserviceable pieces, either in quality or dimensions, should be brought to the bridge. Everything should be delivered where it is to be used. If teams cannot reach that point, men should carry it.

The result of perfect organization and proper strength of parties would be, that the times required for the performance of each of the seven operations above specified would be equal, the stream of material would be steady, sufficient, and unobstructed, and the growth of the bridge would be directly as the time. Such perfection is rarely attained, but it is possible, and should always be aimed at. The strength of parties may be changed from time to time as the work progresses and the needs of each are more clearly seen. This can be done by a word after the organization is effected.

To build a bridge like the Potomac Creek Viaduct, the material being obtainable int he immediate vicinity of the bridge, the following force would be required.

Table, Showing Force Required for Building a Bridge like the Potomac Creek Viaduct.

Engineer Officers.	Field Officers.	Captains.	Lieutenants.	Non-Com's'd. Officers.	Privates.	DUTIES.
1	......	......	......	......	......	In charge of the work.
......	1	......	......	......	......	Commanding the troops.
......	......	6	......	......	......	Commanding companies and for duty as Officers-of-the-day.
......	......	......	1	1	1	Adjutant, Sergt. Major, and Clerk.
......	......	......	1	2	4	Quartermaster, Q. M. Sergts., and Clerks.
1	1	6	2	3	5	Total Field and Staff.
						First Party — Axemen Cutting Logs.
......	......	......	1	......	......	Commanding Party.
......	......	......	......	5	......	In charge of Squads.
......	......	......	......	......	5	1st Squad, cutting logs for 1st tier trestle-legs.
......	......	......	......	......	5	2nd Squad, cutting logs for 2nd tier trestle-legs.
......	......	......	......	......	5	3rd Squad, cutting logs for 3rd tier trestle-legs.
......	......	......	......	......	7	4th Squad, cutting and hewing caps, sills, and stringers.
......	......	......	......	......	3	5th Squad, cutting braces.
......	......	......	1	5	25	Total of First Party.
						Second Party — Loading and Transporting Material.
......	......	......	1	......	......	Commanding Party.
......	......	......	......	5	......	In charge of Squads.
......	......	......	......	1	......	In charge of Teamsters.
......	......	......	......	......	8	1st Squad, loading 1st tier trestle-legs.
......	......	......	......	......	6	2nd Squad, loading 2nd tier trestle-legs.
......	......	......	......	......	4	3rd Squad, loading 3rd tier trestle-legs.
......	......	......	......	......	8	4th Squad, loading caps, sills, and stringers
......	......	......	......	......	4	5th Squad, loading braces.
......	......	......	......	......	10	Teamsters, 3 for 1st. 3 for 2d, 2 for 3d, 1 for 4th, and 1 for 5th Squad.
......	......	......	1	6	40	Total of Second Party.
						Third Party — Unloading and Handling Material at the Bridge
......	......	......	1	......	......	Commanding Party.
......	......	......	......	5	......	In charge of Squads.
......	......	......	......	......	16	1st Squad, carrying logs to first framing platform.
......	......	......	......	......	12	2nd Squad, carrying logs to second framing platform.
......	......	......	......	......	8	3rd Squad, carrying logs to third framing platform.
......	......	......	......	......	8	4th Squad, carrying caps, sills, and stringers.
......	......	......	......	......	6	5th Squad, carrying braces.
......	......	......	1	5	50	Total of Third Party.
						Fourth Party — Framing the Trestles.
......	......	......	1	......	......	Commanding Party.
......	......	......	......	4	......	In charge of Squads.
......	......	......	......	......	12	1st Squad, 4 carpenters and 8 laborers, at 1st framing platform.
......	......	......	......	......	12	2nd Squad, 4 carpenters, and 8 laborers, at 2nd framing platform.
......	......	......	......	......	10	3rd Squad, 4 carpenters, and 6 laborers, at 3rd framing platform.
......	......	......	......	......	6	4th Squad, 4 carpenters, and 2 laborers, auger and pin men.
......	......	......	1	4	40	Total of Fourth Party.

Table, Showing Force Required for Building a Bridge like the Potomac Creek Viaduct, Continued.

Engineer Officers.	Field Officers.	Captains.	Lieutenants.	Non-Com's'd. Officers.	Privates.	DUTIES.
						Fifth Party — Transporting and Raising Trestles.
......	......	......	1	......	......	Commanding Party.
......	......	......	......	6	......	In charge of Squads.
......	......	......	......	......	20	{ 1st Squad, 2nd Squad } Carrying or floating 1st tier trestles.
......	......	......	......	......	20	{ 3rd Squad, 4th Squad } Carrying or floating 2nd tier trestles.
......	......	......	......	......	16	5th Squad, carrying or floating 3rd tier trestles.
......	......	......	......	......	10	6th Squad, manning the hoisting tackle.
......	......	......	1	6	66	Total of Fifth Party.
						Sixth Party — Placing and Bracing the Trestles.
......	......	......	1	......	......	Commanding Party.
......	......	......	......	3	......	In charge of Squads.
......	......	......	......	......	8	1st Squad, placing and bracing 1st tier trestles.
......	......	......	......	......	6	2nd Squad, placing and bracing 2nd tier trestles.
......	......	......	......	......	6	3rd Squad, placing and bracing 3rd tier trestles.
......	......	......	1	3	20	Total of Sixth Party.
						Seventh Party — Laying Stringers and Moving Skids.
......	......	......	1	......	......	Commanding Party.
......	......	......	......	1	10	The Squad, handling stringers and skids.
......	......	......	1	1	10	Total Seventh Party.
						Recapitulation.
1	1	6	2	3	5	Field and Staff.
......	......	......	1	5	25	First Party.
......	......	......	1	6	40	Second Party.
......	......	......	1	5	50	Third Party.
......	......	......	1	4	40	Fourth Party.
......	......	......	1	6	66	Fifth Party.
......	......	......	1	3	20	Sixth Party.
......	......	......	1	1	10	Seventh Party.
1	1	6	9	33	256	Grand Total on the Work.
......	......	......	3	15	56	Supernumeraries, cooks, and camp-guards.
1	1	6	12	48	312	Total strength of the command, equal 6 companies of 60 men each.

Calculation of the amount of transportation required. — The amount and kind of transportation will depend always on circumstances. As a rule, mule teams and army wagons will be employed, although ox teams are more easily handled in the woods. When army wagons are used, their bodies should be removed, and bolsters and side pieces substituted. For hauling very heavy logs, the wagon running-gear is uncoupled, the butts of the logs are lashed on the front axle, and the points allowed to drag on the ground. The hind wheels may be used as hand sling-carts for the transportation of heavy logs to points where they can be loaded on the wagons or carts. Teams of two, or, at most, four mules, will be used. The extra mules — six being the usual team — are supernumeraries, some of which can be utilized at the hoisting apparatus.

Transportation. — The transportation required would be —

10 Army wagons — six-mule teams.
20 Log chains,
500 Feet $1\frac{1}{4}$ inch rope,

Tools. — The tools required would be: —

For the 1st Party. — 20 Felling Axes.
5 Broad Axes.
1 Tape Line.
1 Chalk Line.
1 Carpenter's Rule.

For the 4th Party. [illegible] Carpenter's Hatchets.
[illegible] Sledge Hammers, small — spike drivers.
[illegible] Cross-cut Saws — large.
6 Two-inch Augers.
3 Tape Lines.
3 Carpenter's Rules.
4 Carpenter's Squares.
4 Hand Saws, cross-cut,
4 Hand Saws, rip.

For the 5th Party. — 2 Sets, Four-fold Tackles and Falls, $1\frac{3}{8}$ inch.
2 Beams 25′ x 10″ x 12″ trussed, and having a sheave fitting in a mortice at one end for the fall.
2 12″ Short Rollers.
4 12″ Long Rollers.
2 Capstans, and sets of bars.

For the 6th Party. — 20 Carpenter's Hatchets.
3 Plumb Lines.
6 Hands Saws cross-cut.
6 Hand Crow Bars.

	6 Boat Hooks.
For the 7th Party. —	6 Long Handspikes.
	4 Short Handspikes.
	4 Mauls.
For General Use. —	12 Spades.
	12 Shovels.
	12 Picks.

There should also be a Forge and a Carpenter Shop, with the necessary tradesmen, at the bridge.

Materials and Extra Tools. —

500 Feet, 1¼ inch Rope.
2 Sets, Tackle and Falls, four fold, 1⅝ inch Rope.
6 Sledge Hammers, small — spike drivers.
50 Kegs 7 inch Spikes.
10 Kegs eight and ten-penny Nails.
20 Log Chains.
12 Two-inch Augers.
12 Tape Lines.
36 Felling Axes.
12 Broad Axes.

The Question of Time.— It is assumed that the material is all within five hundred yards of the bridge. In the case of the Potomac Creek Viaduct, it had to be hauled half a mile, from the woods to the railroad, and then transported over a mile by rail. This must have been a drag on the progress of the work, not so much on account of the distance, as the mixing of the material.

Much time was also consumed in constructing the crib-work foundation, which is not a necessity in all cases. Where it is a necessity, as was the case at Potomac Creek, it will be found to be the most tedious part of the work. The best way to proceed with such a work, is to build the several cribs in the woods, just as they will stand in the water, mark the logs, take the cribs to pieces, transport to the river, and rebuild. The officer commanding the axmen, being furnished with the number and dimensions of the cribs, assigns one to each of his squads. As they are finished, the transportation party takes charge of them, and the axemen go to work on a new crib. When the first crib arrives at the river, it is taken in charge by the party of handlers and carried or floated in proper order, to the placing and bracing party, who rebuild the crib in its proper place.

While the crib building progresses, the trestle-framing party prepare their platforms, and make their pattern trestles; and the hoisting, and stringer-handling parties, rig the sliding-beams, and reeve the falls.

It is difficult to estimate the time required for such work, as the proposed organi-

zation was designed for another purpose. Where material is abundant and convenient, a squad of five axemen should be able to build a five log crib in two hours, being assisted in handling the logs by the loading party. Five such squads are at work, and there are say thirty cribs to build: — in twelve hours the work would be done.

There should be a crib under each trestle, where they are needed, and, as we have assumed six feet as the distance between trestles, the cribs should be 4′ x 22′ and bound to each other by stringers pinned on the top, after they are in position.

Time Estimate. —

For organization and instruction,	4	hours.
Issuing tools,	1	"
Crib-work foundation,	18	"
Trestle work.	30½	"
Total.	53½	

This calculation is based upon half an hour to frame a trestle, which will be found ample. The strength and organization of parties are intended to secure a steady flow of material from the woods to the bridge. The bridge should be practicable in 55 hours. It is a railroad bridge, 400 feet long, and 80 feet high, having a crib-work foundation under thirty trestles, five logs high.

The Construction.

Framing the Trestles. — If the bridge like the Potomac Creek Viaduct is to consist of three tiers of trestles, three framing-platforms will be required.

A Framing-Platform consists of three logs a little longer than the sill of the trestle to be made, and thick enough to square 12″. One log is hewed on one side, the others on two adjacent sides. They are laid on, and partly imbedded in the ground at some convenient level spot, at equal distances apart, and parallel to each other; the distance from out to out being the height of the proposed trestle. The log, hewed on one side only, is laid in the middle, hewed side up; the others at the ends, hewed sides upwards and outwards — the upper surfaces of all being in the same horizontal plane. A pattern trestle, previously made, is then laid on the platform and the direction of the legs carefully and permanently marked. The platform is then ready.

Each framing-platform is manned by 4 carpenters and 8 laborers. The legs are brought up by the laborers and placed on the platform, so as to conform to the marks. The carpenters verify the positions and trim, if necessary, at the junctions of the legs, while the laborers lay on the braces — one three-inch plank at the top, its outer edge flush with the outer edge of the framing-platform, another at the bottom in the same way, and a pole across the middle. The carpenter's now spike

on the braces, and the laborers man the cross-cut saws. The projecting ends, above and below and at the sides, are sawed off, and the cap and sill substitutes spiked on. The auger men then bore the requisite holes in the tops or bottoms of the trestle legs, insert the dowels where they are required, and the trestle is finished.

When the auger men are not thus employed they are boring holes in the regular caps and sills, being guided in all their borings by pattern pieces, so that their work will always fit.

If it be a lower trestle, the regular sill is pinned to the bottom instead of the sill substitute, and if it be a top trestle, it is crowned with the regular cap pinned on in the same way.

The dowel is a two-inch pin, driven about half its length, the projecting end being tapered off so as to enter freely into the corresponding hole in the next trestle.

Transporting and Raising the Trestle. — As soon as the trestle is finished, it is taken in charge by the transporting party, and carried, or floated, into position for raising. Rope slings are passed around the cap, or cap substitute, near the ends, the falls are made fast, and the word given to " hoist away."

The Hoisting Machinery is of the simplest kind. It consists of, *the sliding-beams*, *the rollers*, and *the falls*.

The Sliding-Beams are two logs from 20 to 30 feet long, and thick enough to square 12 inches. They are hewed on the upper and lower sides, and morticed at one end to recieve a sheave of size to fit the fall. The same end is provided with an eye bolt, or strap, or other contrivance for attaching the upper block of the tackle.

The Rollers are two short rollers 12″ in diameter placed under the sliding-beams, to facilitate their movement to the front, and to raise the ends of the sliding-beams. They rest upon the outer stringers. When the sliding-beams have been run out the proper distance, the rollers are chocked.

The Falls are two tackle of power equal to the weight to be raised. A gun tackle purchase will be sufficient in most cases. This consists of two single blocks, the rope being attached to the strap of the lower block, passes through the upper block, then through the lower block, then over the sheave in the end of the sliding-beam, and horizontally to the rear, where it is manned by the hoisting squad.

While the trestle is being brought up, the sliding-beams are moved forward until their ends project ten inches beyond the position of the trestle about to be placed.— The distance is permanently marked on the sliding-beams. — The rollers are then chocked, and the shore end of the beams securely fastened down.

If neither mule power nor capstan is used, the stringer and skid men help in the hoisting. When the trestle has been raised sufficiently it is taken in charge by the placing and bracing men.

Placing and Bracing the Trestles. — The placing and bracing party consists of three squads, the first of eight, and the second and third of six men each.

Of the first squad, three on each side stand ready to receive the bottom of the trestle and place it in its proper place. The bottom is pulled inwards to its proper place, and held there by crow bars, or by hand, while it is being gently lowered. As soon as it rests the lowering is stopped. The trestle now has an inclination outwards of about ten inches. While one man at each side remains with his crow bar in front of the sill to prevent a slip, the remaining two on each side turn their attention to the lower longitudinal braces, which the squad whose duty it is, holds ready for them. The inner end of the brace is made fast; the outer end is held in its position until the trestle is brought to the vertical, when it also is made fast.

The seventh and eighth men of this squad are on the level of the top of the trestle, each with a boat-hook, to the neck of which, a plumb-line is attached. When the bottom of the trestle rests in place, and everything is ready to drive the last spike in the lower longitudinal brace, they pull in the top of the trestle gently and steadily, assisted, if necessary, by the men of the second tier sqnad — four of whom, two at each side, are on the same level — until the plumb-lines indicate that the trestle is vertical. The lower brace is then secured, and the middle one also: then, seven and eight let go and assist in putting on the upper brace, provided they are not required in fending off the second tier trestle now being hoisted.

The second and third tier trestles are placed and braced in the same way by their respective squads.

Laying the Stringers. — The stringers will be at least 12′ long so as to rest on three trestles, and there will be no difficulty in slipping them forward, as they will always have two points of support. The middle stringers are carefully guaged and secured: they have to carry the rails. It would be well to lay the track as the bridge progresses, then the stringers could be brought up on hand-cars. No ties are required on the bridge.

If it be desired to use the bridge for common road as well as railroad purposes, it will be floored, over the stringers, and the track laid on the top of the flooring. No ties are required.

SECTION 2.

Military Railroad Truss Bridge.

When an army is obliged to retire before an enemy, and the desire is to retard his advance, it seldom fails to destroy the bridges. This, in the case of wooden bridges, is generally effected by means of fire, and the piers and abutments remain comparatively uninjured.

In the case of an advance along a railroad upon which the army depends for its supplies, the destruction of a bridge puts an effectual check upon its progress. The

army may be thrown across the river by any of the expedients usually resorted to in such cases, but it cannot advance, until its communications are re-established. The rebuilding of the bridge will alone get it out of check.

It is of the highest importance, then, that the army should be able to rebuild the bridge. Preparations for a campaign are not complete until such emergencies are amply provided for. It may be taken for granted that every important bridge on the line of advance will be destroyed, and that their replacement in the least possible time is as important as a successful battle. A careful and energetic commander, therefore, will see to it, not only that bridge material is prepared in advance, but that it, and the men to put it in position, arrive at the crossing in company with his advance guard.

The truss bridge meets the requirements of such an emergency in an eminent degree. It can be prepared in advance to any extent. Its parts can be fashioned by machinery. It adapts itself to any span, and, as its parts are interchangeable, it can be erected without confusion by the labor of the troops. The construction corps of the Army of the Potomac had reached such a degree of proficiency in this kind of work, that General Haupt is able to say in his treatise on Military Bridges, that one thousand feet of such a bridge could be erected by it in a day. It cannot be expected that soldiers, taken indiscriminately from an army, could equal that remarkable feat, but it is a possibility which practice will enable them to reach in time, and which well instructed officers may enable them to approximate, even in their maiden efforts. Every professional soldier, therefore, should know how to erect such a bridge.

There are many varieties of truss, each possessing its own peculiar merits, but the one which recommends itself *par excellence* to the military engineer is the lattice truss. It is not the intention to discuss here, either the general theory of truss bridges, or the special merits of the lattice truss. The problem is, how to erect such a bridge with soldier labor in the shortest possible time, the material being ready to hand.

The material for the bridge. having been prepared in advance, is loaded on flat cars in the reverse order to that in which the pieces will be required. This arrangement is of the greatest importance, as the handling of the material at the bridge is likely to be entrusted to unskilled men. If the pieces can be carried to the bridge just as they are taken from the cars, and arrive there always as they are wanted, it will expedite the work immensely. And this can be done by carefully packing the material.

The material for 1,000 feet of truss bridge can be loaded on fifty flat cars, and carried forward in a single train. It can be so packed, that each car shall carry 20 feet of bridge. The actual weight of a lattice truss bridge is about 1,000 pounds per lineal foot. This gives a load of 20,000 pounds per car. which is well within the limits. Every car should be loaded in exactly the same way, with the same

number and the same kinds of pieces. Except that a set of *wall plates*, *skewbacks*, and *corbels* should be added to the load of every odd car, if they have not been provided for with the false work.

The Bill of Timber required for 1,000 feet of bridge would be: —

28 Wall Plates, 8″ x 12″ and 21 feet long, of white oak.
56 Corbels, 12″ x 12″ and 24 feet long, of white oak.
56 Skewbacks, 12″ x 12″ and 8 feet long, of white oak.
750 Chord Plank, 3″ x 12″ and 32 feet long, of white pine.
250 Truss Posts, 2″ x 10″ and 20 feet long, of white pine.
500 Truss Braces, 2″ x 10″ and 28 feet long, of white pine.
168 Lateral Braces, 5″ x 6″ and 21 feet long, of white pine.
168 Lateral Braces, 5″ x 6″ and 19 feet long, of white pine.
500 Floor Beams, 7″ x 12″ and 19 feet long, of white pine.
125 Stringers, 5″ x 10″ and 32 feet long, of white pine.
3125 Arch Boards, 12″ x 1″ and 16 feet long, of white pine.
250 Track Shores, 2″ x 10″ and 4′ 1″ long, of white pine.
500 Packing Blocks, 2″ x 6″ and 10 inches long, of white pine.
500 Packing Blocks, 6″ x 12″ and 1½ feet long, of white pine.
280 Arch Posts, 6″ x 12″ and 18 feet long, of white pine.
480 Stirrup Blocks, 6″ x 6″ and 2½ feet long, of white oak.
500 Chord Pins, 3″ in diameter and 2¾ feet long, of white oak.
500 Chord Pins, 3″ in diameter and 1¾ feet long, of white oak.
250 Truss Plank Pins, 3″ in diameter and ¾ feet long, of white oak.
1200 Key Pins, 1¼ inch in diameter and 1 foot long, of hard wood.

The Bill of Iron would be: —

2000 Chord Bolts, ¾ inch in diameter and 15 inches long.
324 Corbel Bolts, ¾ inch in diameter and 39 inches long.
64 Corbel Bolts, ¾ inch in diameter and 27 inches long.
85 Lateral Rods, 1¼ inches in diameter and 19¼ feet long.
85 Lateral Rods, 1¼ inches in diameter and 18½ feet long.
480 Suspension Rods, 1¼ inches in diameter and of assorted lengths.
250 Track Stringer Rods, 1 inch in diameter and 6 feet long.
2388 Nuts, ¾ inch.
500 Nuts, 1 inch.
1780 Nuts, 1¼ inches.
4776 Washers, ¾ inch.
500 Washers, 1 inch.
1780 Washers, 1¼ inch.
340 Lateral Shoes.

But setting up the bridge is the second, and least difficult part of the problem.

Scaffolding or *false work* must first be erected; a work, which, under the most favorable circumstances, will take as much time as setting up the bridge.

The False Works. — Assuming that the forethought which prepared the bridge in advance, would not fail to provide for the false work, it will be unnecessary to discuss improvised false work, or any of the expedients resorted to when such preparation has been neglected. It is sufficient to state that the usual expedient is a light trestle bridge, built upon the principles laid down in the last paper, qualified by the consideration that it is merely a temporary scaffolding required to carry at the most 1,000 pounds per lineal foot.

The Suspension Scaffold. — Where false works are provided for in advance, the suspension scaffold is usually resorted to. It is simple, portable, easily put together, sufficiently strong, and may be utilized as an ordinary bridge. It consists of *the cables*, *the wall-plates*, *the sills*, *the trestles*, *the flooring*, and *the stay-ropes*.

The Cables are of wire rope 1½ inches in diameter, and in lengths of 100 feet. The lengths are provided at the ends with swivel-links about ten inches long, and can be united by means of connecting-bolts so that any desired length of cable can be obtained. Eight of these cables — four on each side — are used as a foundation for the false work.

The Wall Plates 8″ x 12″ and 21 feet long, are timbers which belong to the bridge, but are necessary in the erection of suspension false work. Where such false work is used, the wall-plates will be omitted from the schedule of bridge material, as they will go forward with the scaffolding. They are laid on the piers — cross-wise the bridge — flush with the edges, and secured by planks spiked across the top, and braces fitted in between the plates and fastened to the piers by spikes driven into the joints of the masonry.

The Sills are the cross timbers which rest on the cables and support the trestles which carry the foot-way. They are laid at intervals of 15 feet, and secured in the following manner. The cables having been stretched and adjusted, the first sill is spiked to the ends of two planks 15 feet long. It is then, by means of these planks, pushed out from the abutment, their full length. The other ends of the planks are spiked to the wall-plate, and the first sill is secured. The second, spiked to the ends of two other planks, is pushed out 15 feet beyond the first, and secured by spiking the other ends of the planks to the first sill; and so on. The planks connecting the sills rest on the four cables at each side of the bridge, and can be utilized as a foot bridge for the workmen.

The Trestles consist of *two legs*, *a cap*, and *bottom braces*. The legs are pieces of scantling six inches square and ten feet long, perforated with holes three inches apart, throughout their length. The cap is a piece of 6 inch scantling spiked on the top of a pair of legs. The bottom braces are two planks having holes at the ends to match the holes in the trestle-legs, with two key-bolts attached by a chain to one end of each. The trestles are so light that they can be set upon the scaffold.

The operation consists in laying the bottom braces across the cables at one of the sills, raising the trestle until the cap is on the line of the bottom of the lower chord of the bridge, keying it at that height by passing the key-bolts through the proper holes, and bracing it longitadinally by nailing light strips connecting it with the abutment,. or the last trestle erected.

The Flooring consists of light plank laid longitudinally across the trestle caps, so as to form an eight-foot footway along the middle of the scaffolding.

The Stay Ropes are used for lateral bracing, to prevent, as much as possible, the swaying motion of the structure. They are fastened to the cables and stretched obliquely to the shores or abutments, and anchored.

Construction of the False Works. — In replacing a bridge, assuming that the piers and abutments remain intact, and that suspension false works, and material for a lattice truss bridge have been prepared before hand, the first thing to be done is to erect the false work. This includes the following operations: —

1. Placing the Wall Plates.
2. Stretching the Cables.
3. Placing the Sills.
4. Erecting the Trestles.
5. Laying the Footway.
6. Stretching the Stay Ropes.

Placing the Wall Plates. — To do this, some men must find their way to the tops of the piers. This is not always an easy task. In all cases, a boat of some kind is indispensible. If the piers are not very high above the water, that is, not over eight or ten feet, a wire is passed across the river on the up-stream side of the piers, by means of the boat. Returning, the men in the boat having provided themselves with poles for the purpose, raise the wire to the tops of the piers. A rope is then attached to one end of the wire, pulled over until it extends from bank to bank, and temporarily secured. An active man then siezes the rope as near the pier as practicable, and, assisted, if necessary, by the men in the boat, climbs to the top. A rope ladder, previously prepared, is then thrown to him, made fast to spikes or pins driven in the joints of the masonry, and four more men mount the pier. A light pair of shears is then sent up and mounted, the guy-rope being secured to a spike driven into a joint of the masonry on the side of the pier. Then, the two wall plates are hoisted, and the tools and material necessary to lay and secure them sent up, and the boat proceeds to establish a party and material on the next pier, and so on till all are manned and equipped.

Stretching the Cables — The cables are sent across the river, one at a time, on the up-stream side, as was done in the case of the wire, and hoisted to the top of the piers by means of the shears already in position. There are eight of them in all, and they are placed, four on each side in *juxta-position.* The ends on the *near* bank are securely anchored; those on the *opposite* bank, temporarily fastened until

the cables are adjusted. The ends on the near bank are secured first, for two reasons. First, the tools are there; and second, adjustment begins there, so that work may proceed at once, as soon as the first span is adjusted.

Adjusting the Cables, is giving them a uniform and sufficient sag, which should be about one-tenth the span. Adjustment begins at the first span. A Y Level, or any surveying instrument that will strike a level, or two parallel straight-edges fastened horizontally by means of a common spirit-level, or some other contrivance, is set up at the level of what should be the lowest deflection of the cables, and in a position, from which, every span can be seen. The cables of the first span are then adjusted, by slackening or tightening the individual cables. This is done by the men on the piers, with handspikes and straps which lay hold of the cables. When a cable hangs at the true level it is secured by staples driven in the wall-plate.

When the cables of the first span are adjusted, attention is turned to those of the second, and so on till all are adjusted. Then the temporary fastening on the farther shore is replaced by a permanent anchorage.

Placing the Sills. — The method of performing this operation has already been described when describing the sill. (*p.* 17).

Erecting the Trestles. — Already described. (*p.* 18).

Laying the Footway. — Already described. (*p.* 18).

Stretching the Stay Ropes. — The stay-ropes are attached to the cables at the first and second trestles on each side, their shore ends inclining outwards from the bridge are securely anchored on the bank. In a similar way, the two trestles nearest the piers on each side, are braced to the sides of the piers. The stay-ropes are intended merely to prevent swaying. They should be taut, but without strain sufficient to displace the cables.

The six operations of erecting the false work, are performed by separate parties, each under the command of a commissioned officer; each party proceeding with its work as soon as the one preceding, has progressed sufficiently to make it possible.

The strength and organization of parties is an important but not difficult question. It may be assumed that labor will be abundant, and at hand. If the six officers commanding parties be familiar with their work, and the officer commanding the whole supplies them from time to time with all the men they can use, there will be no necessity for a permanent organization.

The Bridge.

The truss bridge derives its power to support a load from the arch and tie-beam. If the load were immovable, nothing more would be required, except, perhaps, such lateral bracing as would secure the arch in its position. But bridges are required to sustain, in addition to the permanent immovable load of their own weight, the movable and variable load of passing carriages. The action of such a load upon an untrussed arch tends to change its figure and thus destroy its strength. To resist this change of figure is the function of the truss.

The Lattice Truss. — The truss best adapted for military purposes is the lattice truss. It is so simple that it can be readily set up by unskilled labor. Its parts, of the same class, are interchangeable. It can be manufactured in advance, and it will adapt itself to any span.

The principle parts of a lattice trussed arch are: —

The Wall Plates.
The Corbels.
The Chords.
The Truss Plank.
The Arches.
The Skewbacks.
The Lateral Braces.
The Stirrup Blocks.
The Stringers and Floor Beams.

The smaller pieces, such as *chord-pins*, *key-pins*, *truss-blocks*, *truss-pins*, *packing-blocks*, *suspension-rods*, *lateral-rods*, *chord-bolts*, *corbel-bolts*, *stringer-bolts*, *nuts*, *washers*, and *shoes*.

The Chords. — There are two sets of chords in a truss bridge, the lower, and the upper. The lower chord is the tie-beam of the arch. The top of the upper chord is tangent to the arch at its highest point, and serves to maintain the truss-plank in their position. The chords are built up beams composed of planks 32 feet long, 12 inches wide, and 3 inches thick, laid so as to break joints, and pinned and bolted together. Except at the ends, any chord-plank will fit in any part of any chord, in any way. This is a great advantage in a military bridge.

The Lower Chord consists of four built up beams, two at each side of the bridge, separated by the ends of the truss-plank. Each beam consists of four or six chord-planks, bolted, pinned, and keyed together.

The Upper Chord is exactly like the lower one, except that it consists of two or three, instead of four or six chord-planks.

The Chord-Plank is of white pine, of the dimensions already given, and having three-inch auger holes along its middle line, at intervals of four feet: that is, there are seven holes, four feet apart from center to center, in the plank, and half a hole at each end. The boring is generally done by machinery, and with such exactness, that the holes will match whether the plank be upside down, or end for end, and the half holes in the end of one plank will exactly match with those in the ends of any other against which it may be abutted.

Midway between the pin holes just described, bolt holes, one inch in diameter, also bored by machinery, penetrate the plank. They are intended to receive the chord-bolts, ⅞ of an inch in diameter, the extra ⅛ of an inch being sufficient to overcome any difficulty which might be experienced in passing the bolt through holes of the exact size

The Truss Planks consist of posts and braces. The posts are of plank 10 inches wide by 2 inches thick and 21 feet long; the braces, of similar plank 28 feet long. The posts have a 3-inch hole in the middle, and one at each end. The braces have five such holes; one at each end, through which they are pinned to the upper and lower chords, one in the middle, through which they are pinned to the posts, and one in the middle of each half, throngh which they are pinned to each other. Braces are distinguished from each other by the directiou of their inclination; those which slope towards the key of the arch are called *braces*, those which slope away from the key, *counter-braces*.

The Arches. — There are four arches to each span, one on each side of both the trusses. They are made of inch boards 12 inches wide and 16 feet long, sprung into position flat side up, securely nailed down layer upon layer and breaking joints, to a thickness of 18 inches. Sometimes the arch is composed of three layers of boards flat side up, then a layer of twelve boards on edge, forming the sides of a circumscribed polygon, then three more layers laid like the first, all securely nailed together.

The Skewbacks are pieces of timber 12 inches square and 8 feet long, extending from the heel of the arch to the end of the lower chord. They are intended to resist the horizontal thrust of the arch, and are securely bolted to the lower chord by iron bolts one inch in diameter, passing through the skewback, chord, and corbel at intervals of 9 inches. Sometimes these bolts are inserted with an inclination so as to increase their resisting power. Between the bolts, and in the joint between the chord and skewback, 3-inch holes are bored horizontally, into which, pieces of 3-inch pipe are driven to prevent slipping.

The Lateral Braces are pieces of 5″ x 6″ scantling. Those for the top are 19, those for the bottom 20 feet long. The bottom braces are spiked to the inner sides of the lower chords, and cross each other diagonally under the floor beams. The top braces are similarly spiked to the inner sides, or, on the top of the upper chords. Before the top lateral braces are secured, the verticality of the trusses is tested — and if necessary corrected — by the plumb-line.

The Stirrup Blocks are pieces of white oak, 6-inches square and 2½ feet long, attached to the suspension rods under the lower chords. Sometimes they extend clear across the bridge and are supported by a suspension rod at each end, in which case, the bottom lateral braces are spiked on their upper surfaces.

The Floor Beams are of white pine 7 x 12 inches and 19 feet long. They are laid across the lower chords at intervals of two feet, and support the stringers. The floor beams are secured in their position by ribbons of plank spiked to their upper surfaces immediately over the chord beams.

The Stringers are of white pine 5 x 10 inches and 32 feet long. They carry the track, and are laid on the floor beams according to the guage of the road.

The Corbels are pieces of pine timber 12 x 12 inches and about 24 feet long.

They are laid on the wall-plates, and extend under the lower chord, both ways from the pier, a distance of about 8 feet. They reinforce the lower chord under the feet of the arches.

The Wall Plates. have already been described.

The pins, and metal parts need no special description.

Construction.

The operations to be undertaken in setting up such a bridge, the false work being in position, are:—

1. Distributing the Material.
2. Laying the Lower Chords.
3. Pinning the Lower Chords.
4. Bolting the Lower Chords.
5. Boring for Key Pins.
6. Driving Key Pins.
7. Preparing Truss Plank.
8. Setting Truss Plank.
9. Setting the Upper Chord.
10. Pinning the Upper Chord.
11. Lateral Bracing.
12. Building the Arches.
13. Laying the Road Beams.
14. Attending to Lateral Rods, Skewback Bolts, Stirrup Blocks, and Stringer Bolts
15. Laying the Stringers.

1. **Distributing the Material.** — The material is on the cars, in the reverse order to that in which it should lie on the false work. The workmen having assembled at the train are formed in two ranks. One commissioned officer, with as many non-commissioned officers as he may require to assist him, is in charge of the work at this point.

A non-commissioned officer and four men mount upon the first car to be unloaded, and, under the direction of the officer in charge, get ready, and place on the carriers' shoulders, such pieces as may be designated. As soon as the piece is indicated the non-commissioned officer calls for the number of men nocessary to carry it, and that number at once step forward from the right of the line, and present their shoulders to recieve the load. Having received it they start for the bridge. Another piece is indicated, another call made, and another stick follows the first: and so on. When the stream of material is once fairly started there will be no difficulty in keeping it flowing.

Order and regularity must be maintained. The rules of the road are "*keep to the right*," and there must be no halting. As the bearers return empty they will

fall in in rear nf those waiting for their loads, and move up promptly when their turn comes, in answer to the call of the non-commissioned officer.

The officer in charge at the train will see at a glance, as soon as the work begins, whether or not the detail is sufficient in strength, and can increase or diminish it accordingly. It is not well that men should wait too long for their loads. The four men on the car should be relieved from time to time for rest.

At the bridge a commissioned officer is in charge, and, with the assistance of two non-commissioved officers, attends to the disposition of the material as it arrives, maintains order, and keeps the men in motion. There must be no halting on the bridge.

The first piece to arrive will be a stringer. It is deposited, without shock on the right, well off the foot way, yet not so near the side as to interfere with the laying of the lower chord. The men then step to the other side of the footway, face in the opposite direction, and march back in Indian file.

The second party brings a stick which belongs on the left side. It keeps to the right until it is opposite the place where the stick should lie, then halts, steps to the left, deposits the stick, faces to the rear, and returns as did the first party.

The first pieces to arrive are stringers, then the floor beams, for a certain length of bridge. As these pieces are not required until the very last, and may be in the way, they might without detriment be piled on the right and left at the end of the bridge, and carried forward when they are wanted.

The lateral braces as they arrive are distributed evenly over the footway. The upper chord-planks are laid on the lateral braces. The truss-planks on the top of all. The lower chord-planks as they arrive are laid at once in position, and the men having their placement in charge, can proceed with their work, as they are well out of the way of the carriers.

And So the work proceeds until the distribution of the material is complete.

Laying the Lower Chords. — The first eight planks on both sides of the bridge must be laid in a certain order, to ensure breaking joints throughout. They are of unequal lengths, namely, 4, 8, 12, 16, 20, 24, 28, and 32 feet. They should be laid in the following order, first the shortest, then the longest, then the next shortest, and the next longest, and so on throughout.

The first built up beam would, therefore, be commenced with the 4, 32, 8, and 28 feet planks, in the order named. The second would have the 12, 24, 16, and 20 feet planks, in the order named. The third and fourth beams, on the opposite side would be commenced in precisely the same way. After these end-planks are laid, the rest are of uniform length and will fit anywhere.

Eight men — four on each side — will be sufficient for this part of the work. To facilitate the placing of the chord-planks, a strip of board — one of the footway boards might be used for this purpose — should be nailed on the sills to mark the position of the inner edge of the chord, and thus be a guide to the layers of the chord-planks.

When the chord layers have advanced 64 feet with their work the next squad begins.

Pinning the Lower Chords. — This party consists of four men — two with mauls, and two serving pins and packing blocks. It drives pins in every second hole, that is, at the points where there is to be no intersection of truss-planks. The absence of the truss-planks at these points creates the necessity for packing blocks. The party, therefore, drives four 33-inch pins in every 32 feet of chord.

Bolting the Lower Chords. — This will require eight men, four with wrenches tightening the nuts, and four serving bolts and washers, and starting the nuts as far as they will go by hand. The bolts are inserted from the outside of the outer, and the inside of the inner chord-beam. The nuts, therefore, will be in the 6-inch space between the chord-beams.

Boring for Key Pins. — There are 48 holes 1¼ inches in diameter and 12 inches deep to be bored in every 32 foot section of the lower chord, on both sides of the bridge. This will require two squads of eight men each. Care must be taken to center the auger exactly in the joints between the chord-planks, and bore vertically.

Driving the Key Pins. — Two men with mauls, one on each side will be sufficient for this work.

Preparing the Truss Planks. — This will require four men, two at each side. The work consists in selecting the pieces, that is, getting two braces and one post together, the post in the middle, and the holes in the lower ends matching. These are tied by nailing a packing block 2 x 6 x 10 inches on the side. They are then handed to the men setting up the truss-planks.

Setting the Truss Planks. — This reqnires six men, three on each side of the bridge. One raises the three truss-planks which are bound together, assisted, if necessary, by the second, who also inserts the pin, and helps to hold the planks in position until it is fairly entered. The third, provided with a maul, drives the pin. The second, while this is being done, removes the packing block which ties the three pieces together, inclines the counterbrace backwards until it crosses the brace last set up at the middle, places the packing block between the two — the packing block has a 3-inch hole in the middle — holds them while No. 1 inserts a pin, and No. 3 drives it home. They then proceed to the next set.

Setting the Upper Chord. — This requires the erection of a temporary scaffoiding, which may be improvised by nailing boards, at the proper height, to the posts. The floor board of the false work previously used as a guide for the lower chord can be used for this purpose.

As soon as six sets of truss-planks have been erected, spread, and pinned at the middle, the work of setting the upper chord begins. Eight men are required.

The same principle will be followed in placing the end planks as was observed in placing those of the lower chord. Their lengths will be 8, 16, 24, and 32 feet. The chord-beams consist of two planks each. The first will have the 8 and 32 feet planks, the second, the 16 and 24.

If the false work has settled, which it is very apt to have done, there will be difficulty in getting the truss-planks into position for pinning to the upper chord. The remedy is in correcting the level of the lower chord, by driving wedges where it has settled.

Pinning the Upper Chord. — Four men — two on each side — will be sufficient. Two driving and two serving.

Placing the Lateral Braces. — Eight men can be employed in this work, two at each side below and above. The non-commissioned officer will attend to the plumb-line.

The braces are put in diagonally, crossing each other at the middle. Two men, one at each side of the bridge below, hold the brace in position, and the other two spike it to the inside of the lower chord. The top lateral braces may be spiked on the top of the upper chord by the four men there for that purpose; but, before spiking the upper braces, the plumb-line will be applied and the verticality of both trusses assured.

Building the Arch. — As soon as one span of the truss has been erected, the arch builders go to work. Four carpenters on each side, placing and nailing arch boards, two on each side boring holes for the suspension rods, and two on each side inserting the rods — sixteen men in all.

Attending to Bolts and Rods. — Four squads of four men each. The first attends to the lateral rods above and below, the second to the skewback bolts, the third to the stirrup blocks, and the fourth to the stringer bolts.

Laying the Road Beams — will require four men. The beams are laid two feet apart resting on the lower chords, and secured by a ribbon of plank, spiked on over each chord beam.

Laying the Stringers — will require four men. No organization can be prescribed beforehand that will be perfect in all cases, but changes can readily be made by the officer in charge whenever they appear to be necessary.

Recapitulation.

Omitting the detail for distributing the material, which will be a variable one depending upon the distance of the material from the bridge, there are —

		Non-Com. Officers.	Privates.
1st Squad.	Laying Lower Chords	1	8
2nd Squad.	Pinning the Lower Chords Bolting the Lower Chords	1	4 8
3rd Squad.	Boring for Key Pins Driving Key Pins	1	16 2
4th Squad.	Preparing Truss Plank Setting Truss Plank	1	4 6
5th Squad.	Setting the Upper Chord Pinning the Upper Chord	1	8 4
6th Squad.	Placing Lateral Braces	1	8
7th Squad.	Building the Arch	1	16
8th Squad.	Attending to Bolts and Rods	1	16
9th Squad. 10th Squad.	Laying Road Beams Laying Stringers	1	4 4
	Total at the Bridge	9	108

At least one commissioned officer, besides the engineer, should be constantly at the bridge.

As the work progresses, the necessity for changing the strength of squads may become apparent. This can be done without difficulty by assignments from the supernumeraries, or by transfers, always remembering that too many men on the bridge will hinder the work.

SECTION 3.

Military Bridges on Common Roads.

For common roads there are two distinct kinds of military bridges. First, — the improvised structure, hastily erected — generally on the ruins of a destroyed bridge — out of any available material, for the immediate passage of an army or detachment in pursuit; and, Second, — the more substantial structures erected on important lines of communication.

As a rule, the second will be built by the construction corps, or, if no such organization exists in the army, by some officer specially qualified for the work, with a selected detail of workmen.

The first should be built by the officers and men who first arrive at the crossing,

with such tools, and out of such material as may be available. Nothing short of absolute impossibility or positive orders, should deter them from at once undertaking the work. Any bridge, however rude, that they may produce, if promptly produced, and strong enough to carry the troops across, will be of more value to the army than any pretentious structure which would take longer time to build.

Improvised Bridges.

The Stringer Bridge. — If the span be 25 feet or under, the abutments intact, and timber of sufficient length and strength exists in the vicinity, the construction of an improvised stringer bridge will be easily and readily accomplished. Labor will always be abundant, and it may be assumed that axes — the only tool required except it be an auger — will be sufficiently so for the work.

The operations to be performed are : —

1. Cutting the timber.
2. Carrying the timber.
3. Placing the stringers.
4. Laying the flooring.

Cutting the Timber. — The rule in such cases is, put as many men to work as can be conveniently used. Two axemen to each stringer will fell and prepare them in a very few minutes. Six stringers will be required. In rough, improvised structures, all errors in the question of strength should be unmistakably on the safe side.

Fifty flooring poles, 6 inches in diameter and 12 feet long, will be required. These can be cut, after the stringers, in a very short time. Altogether, fifteen minutes should finish the work in the woods.

Carrying the Timber. — Men enough should be assigned to this part of the work to carry all the material at one trip. The stringers to have a bearing of two feet at each end will be 29 feet long, and, assuming that they are 10 inches in diameter, will weigh 643 lbs. each. This is a good load for 10 men with handspikes. Sixty men, therefore, should be detailed to carry the stringers. The flooring poles, 6 inches in diameter and 12 feet long, will weigh 97 lbs. each, an easy load for two men. The weights are calculated upon a basis of 41 lbs. to the cubic foot, which is taken from the tables of strength of materials.

Crowding about the bridge should be prohibited. When men have deposited their load they should be required to stand aside.

Placing the Stringers. — While the material is being prepared, the officer in charge of the work ascertains the depth of the chasm, and makes preparations to jump the stringers across the span. For this purpose he requires two jumping poles, strong enough to bear the weight of a stringer, and a little longer than the hypothenuse of the right-angled triangle, the base and perpendicular of which are respectively *three fourths* the width, and the depth of the chasm.

The weight of the stringer being 643 lbs., the weight to be supported by each pole will be 322 lbs. Assuming that 20 feet is the length of the poles, as determined by solving the right-angled triangle above referred to, and making the proper substitutions in the formula, gives the diameter

$$D = \sqrt[4]{L^2 w \times 1.7 e} = 4.36 \text{ inches.}$$

Taking $4\frac{1}{2}$ inches as the diameter of the jumping poles at the small end, which will be making a large allowance for safety, the weight of the poles will be 122 lbs. each, an easy load for two men. These should arrive at the bridge as soon as the first stringer.

When the first stringer arrives, it is temporarily laid on the abutment as a wall plate, and chocked. The second and the third are slid out over the chasm a little more than one fourth their length, so as to make a footway for that distance. One of the jumping poles is then pushed out butt end first, until it nearly balances on the wall plate stringer. The bight of a rope is then passed around it, a little in advance of its center ot gravity, by means of which a man on the footway supports the butt, while the pole is being slipped forward, until it reaches the place where it ought to rest. While this is being done, the ends of the stringers which constitute the footway are held down.

The second jumping pole is put in position, by similar means, on the other side of the footway. The two stringers are then drawn back, the jumping poles are crossed and lashed about two feet above the level of the abutment, and a guy rope is attached, long enough to reach across the stream.

A stringer is then laid in the crutch of the jumping poles, and pushed forward until it is nearly balanced. It is then permitted to rest in the crutch, and pushed forward, carrying the jumping poles along with it, until its end is over the opposite abutment. Four men now cross over on the log — steadying themselves by means of the guy rope, held taut for the purpose — lift the stringer out of the angle of the jumping poles, and, in concert with others on the opposite abutment, roll it to one side and place it.

As soon as the stringer is clear of the jumping poles, they are pulled back by the guy rope, another stringer is jumped across the span, and so on until all are across and placed.

Stringers should be laid about two feet apart from center to center, and with the natural bend of the stick, up.

Laying the Flooring. — This is done after the style of the corduroy road, and should not take more than five minutes. The column can now pass on, while the bridge is being finished by pinning on a ribbon of poles to hold down the ends of the flooring, and erecting handrails, if such adjuncts be deemed necessary. It is always well to cover the roadway of such a bridge with straw, to lessen the jolting of carriages.

The delay on account of the bridge should not have exceeded one hour.

Strength of the Bridge. — An important question which should never be neglected is, — "What is a safe load for the bridge?"

There is neither time nor necessity for entering into the niceties of mathematics in determining this question, so long as the error is always kept on the safe side. It is assumed that some officer has a pocket-book containing tables of strength of materials, and formulæ for calculating stresses on beams, or, that he has posted himself on these points as to the timber of the country, before the campaign began.

The formula for transverse strength is: —

$$W = \frac{bd^2}{L} CS.$$

Where W = Weight that will produce rupture.

b = Breadth of beam.

d = Depth of beam.

L = Length of beam.

C, a co-efficient depending on the method of support of the beam. — See Military Railroad Trestle Bridges, Page 2, et seq.

S = Strength taken from the table, which for yellow pine is 112 lbs.

Suppose the material be yellow pine, and that the stringers — round logs 10 inches in diameter, — would square 8 inches. In calculating their strength they may safely be considered as of that size. They are supported at both ends, and the stress upon them will be greatest when the load is at the middle. The value of C in the equation will therefore be 4. The value of S, as already stated, is 112 lbs. Making these substitutions in the formula, and reducing, gives W = 9175 lbs. Deducting fifty per cent. for safety, leaves 4587 lbs., as the supporting power of a single stringer. From this, the weight of that portion of the stringer which does not rest on the abutments must be deducted, namely: —

No. cubic feet in stringer × weight of cubic foot.

That is, $13\frac{1}{2} \times 41 = 554$ lbs. Deducting this from the supporting power, leaves, 4,033 lbs. per stringer, and for the five stringers — the outside ones are only counted halves — 20,165 lbs.

This must be further diminished by the weight of the flooring which is ascertained thus: —

Area of cross section of stick × length × number of sticks × weight of cubic foot.

$$\text{or,} \quad (.25 \times .7854) \times 12 \times 50 \times 41 = 4830.$$

This load, being distributed uniformly, creates a stress only one half of that which it would create if applied at the middle. The weight of the flooring, therefore, in its effect upon the strength of the bridge, may be set down at 2415 lbs, which deducted from the supporting power of the stringers, leaves an available capacity of 17,750 lbs.

Crowded infantry, marching by fours, weigh about 500 lbs. per lineal foot, or 12,500 lbs. on the whole bridge. If this entire load were collected at the middle of the bridge, it would still be within the limits of its capacity by over 5000 lbs.

Cavalry in column of fours, even when checked up and crowded, weigh only 700 lbs. per lineal foot, or 17,500 lbs. for the whole bridge, which is 250 lbs. less than its capacity even if applied at the weakest point.

Field artillery in column of sections weighs 400 lbs. per lineal foot, and is of course within the limit; but a siege battery, consisting of 4.5 inch guns, and weighing 925 lbs. per lineal foot, or 23,125 lbs. for the whole bridge, would be, under the supposition assumed for the other arms, 5,375 lbs. beyond the safety limit.

The above example is merely intended to illustrate the methods of calculation usually followed in the field, and does not pretend to that exactness which less urgent circumstances might demand. It is an approximation to the truth with the certainty that the errors are on the safe side.

Where no growing timber is available, material can sometimes be obtained by the demolition of buildings. A barn will generally furnish beams of sufficient length and strength for a bridge of 25 feet span, that will carry infantry, cavalry, and field artillery.

The rafter ties of such a building will perhaps be 3 x 9 inches and at least 30 feet long. With 12 such, laid in pairs as stringers, and a flooring of the same material, a bridge can be constructed that will sustain a service load of 22,300 lbs.

Where the available timber is too light for stringers, built up beams may be resorted to. Thus, 5 x 6 scantling can be manufactured into 6 x 10 built up beams, by pinning one scantling on the top of another. The pins should be of hard wood, 2 inches in diameter, carefully driven, sawed flush, and wedged at both ends. Key pins should be driven in holes bored along the joint, and a plank nailed on the sides, to prevent slipping. A built up beam is thus obtained, which will sustain a load, at least four fifths as great as the solid beam of like dimensions.

The Scarfed Stringer Bridge. — Where stringers of sufficient length to reach across the span cannot be procured, or where they are too heavy for convenient handling, or jumping across, resort may be had to the scarfed stringer.

It is assumed, as in the last case, that the bridge is to replace one destroyed; that the abutments are intact, and both accessible, and that material can be procured on both sides.

For a span of 25 feet, six stringers 25 feet long and ten inches in diameter, are brought to each abutment, their smaller ends prepared for scarfing — that is, hewed on their upper side for a distance of 18 inches — and then pushed out from the abutment a distance of 10 feet. They are laid 2 feet apart from center to center, their shore ends securely anchored down and loaded, by laying a corduroy road of heavy logs gradually diminishing in size, from the shore ends to the edge of the

abutment. The work on both sides proceeds simultaneously. Six short stringers, 8 feet long and 10 inches in diameter, are now brought forward, 3 on each side, prepared at the ends for scarfing — that is, hewed on the under side, in this case at both ends, a distance of 18 inches — passed across the gap, laid accurately on the long stringers two 3-inch auger holes bored at each end through both stringers hard wood pins driven and wedged at the ends, and the flooring poles laid, and the bridge is finished. The flooring poles on the bridge will be light, those on the short stringers 5 inches in diameter.

The scarfed stringer bridge may be applied to a 30 foot span, by slipping the long stringers out a distance of 12 feet from the abutments, securely anchoring the shore ends and loading them as before, and bracing each long stringer by a piece resting in a niche in the abutment just above the water, and driven into a notch on the under side and near the end of the stringer. The short stringers in this case should be 9 feet long. They are prepared, placed, and secured, as in the last case, and the bridge is finished by laying the flooring as before.

The Trussed Stringer Bridge. — For span of 30 feet, and with material obtained from demolished buildings, no piece of which is longer than 25 feet, resort may be had to the trussed stringer bridge.

The construction of the trussed stringer bridge requires some skilled labor and much sawed material, and is therefore rarely undertaken. Under the circumstances cited however, it will be found as easy a solution of the problem as any other.

The materials required, all of which can be obtained from the demolition of almost any building are —

12 Stringers, 2″ x 9″ and 25 feet long.
12 Heel pieces, 5″ x 6″ and half the length of the stringers.
12 Horizontal ties, 3″ x 9″ and 12 feet long.
12 Anchoring stakes, 5″ x 6″ and 6 feet long.
12 Truss braces, 5″ x 6″ and 20 feet long.
5 Cross braces, 6″ in diameter.
40 Flooring planks, 3″ x 9″ and 12 feet long.

While the material is being prepared, trenches are dug across the road behind the masonry of the abutments. These trenches should be about 4 feet wide, and as deep as practicable. The feet of the anchoring stakes are laid crosswise in the bottom of the trench, two feet apart from center to center.

Anchoring-stake feet may be made of any piece of large timber about four feet long. They are laid as just described, and the anchoring stakes, which consist of 5″ x 6″ scantling, are spiked or pinned to them, sometimes with an inclination to the rear, to increase their holding power.

Heavy logs are then laid lengthwise the trench, on the feet of the anchoring stakes, and the trench is filled up and thoroughly tamped.

Meantime the heel-pieces are being prepared for the braces; that is, having

notches cut in the proper places and at the proper angle, and dowel holes bored in what will be the direction of the braces when in place. This is purely carpenter's work, and no general rule can be given for its performance. The best way is to fit a brace, heel-piece, and stringer, together, just as they will be when in the bridge, mark out the heel-notch and direction of dowel-pin, and thus obtain a pattern by which to cut and bore the others.

Placing the Heel-Pieces. — The heel-piece weighs about 110 lbs. Lay it near and parallel to the edge of the abutment. Place a horizontal tie under each end, that at the head accurately for pinning. Bore through tie and heel-piece and drive the pin. Push the ties upon which the heel-piece rests, outwards, until the heel-piece is just clear of the abutment, holding down the shore ends of the ties. Pass the bight of a rope round the foot of the heel-piece. Withdraw the loose tie. Lower away with the rope, permitting the pinned tie to turn in its place, until the heel-piece hangs in position. Then pin the horizontal tie to the anchoring stake.

These operations proceed simultaneously on both abutments until all the heel-pieces are placed.

Placing the Truss Braces. — The braces having been prepared — that is, having had dowels inserted in their heel ends — are laid on the abutment, their feet projecting beyond the edge a very little less than half their length, and a cross brace pinned, or lashed on the middle, thus tieing the six together. This is done on both abutments.

On the first abutment, a cross brace is passed under the shore ends of the truss braces, and securely pinned to each, about three feet from the ends.

On the second abutment, a cross brace is similarly passed under the shore ends of the truss braces and lashed within four feet of the ends.

On both abutments, three stringers are placed under the braces, one at each end, and one at the middle, their ends projecting about 6 inches beyond the edge of the abutment. These are the levers by which the braces will be lowered into place.

Three guy ropes are attached to the upper cross braces on both abutments, one at each end and one at the middle, and posts driven to make fast to.

Everything being in readiness, the levers are manned, the guy ropes are manned, and two men stand by to raise each truss brace. At the word, the braces are raised, and revolved about the middle cross braces until they stand vertical, supported by the levers under the middle cross braces. A turn is now taken by the guy-rope men round the posts.

The heels of the truss braces are now over and in front of their respective notches, the whole weight supported by the levers, the guy ropes taut, without strain.

The next operation is to enter the dowels in the holes. To effect this, slack off the guy ropes a little, and rotate the truss braces. As soon as their tops pass beyond the perpendicular, their heels will enter the notches. A little careful manipulation of the levers is now required in directing the dowels. When it has been accomplished, the guy-rope men ease away gently, and the levers are withdrawn.

When the tops of the truss braces nearly meet in the middle of the span, the three stringers which had been used as levers on the first abutment, are launched forward until their ends rest on the upper cross brace. Three men cross to the middle from the first abutment, unfasten the upper cross brace on the opposite side, pull it up hard into the angle opposite the upper cross brace already fixed, and secure it. The truss is now locked. The guy ropes are slacked and removed, the fifth cross brace is laid on as a ridge pole, the stringers are placed overlapping on the ridge pole, the flooring is laid, and the bridge is finished.

The Trussed Trestle Bridge. — For spans of 30 feet and upwards the simple stringer bridge is no longer practicable, owing to the weight of the timber required, and resort may be had to what is called the trussed trestle bridge. Where suitable timber can be found, and ropes for lashings are available, such a bridge can be erected in about the same time as the stringer bridge.

It is assumed, as in the last case, that the bridge is to replace one destroyed, and that the abutments are intact. The span is 30 feet, and both sides are accessible and equally provided with available material.

The following material will be required: —

4 Trestle legs, 8 inches in diameter and 25 feet long.
2 Trestle caps, 4 inches in diameter and 14 feet long.
2 Longitudinal braces, 6 inches in diameter and 20 feet long.
2 Girders, 8 inches in diameter and 13 feet long.
2 Trestle braces, 4 inches in diameter and 13 feet long.
12 Stringers, 6 inches in diameter and 14 feet long.
6 Stringers, 6 inches in diameter and 8 feet long.
60 Flooring poles, 4 inches in diameter and 12 feet long. —
and a supply of lariats, or a coil of 1½ inch rope.

The operations to be performed are: —

1. Making the Trestles.
2. Placing the Trestles.
3. Laying the Stringers.
4. Laying the Flooring.

Making the Trestles. — Two trestles are required, one on each side. The material having been delivered, the work on both progresses simultaneously.

The trestle legs are laid on the abutments, with their feet projecting one fourth their length beyond the edge, the legs of No. 1 being 13 feet apart, that of No. 2 12 feet.

The cap of No 1 is laid across the legs within 12 inches of their tops, and lashed. The cap of No. 2 is placed under the legs, 18 inches from their extremities, and lashed. Its ends will project about 9 inches beyond the legs on each side.

The braces are passed under the trestle legs at the middle and lashed.

Placing the Trestles. — While the trestles are being made, niches are knocked out of the abutments to receive the feet of the trestles, or, if that be impracticable, foundation trestles are constructed and placed. If niches be practicable they should be made as far below the top of the abutment as the brace is above the foot of the trestle.

A Foundation Trestle — consists of two legs, a cap, and two braces. The legs should be substantial — 10 inches in diameter — and long enough to reach from the bottom of the stream to the point already indicated for the niches. The cap need not be so strong — 8 inches diameter will be sufficient, and 14 feet long. The braces, 6 inches in diameter and 6 feet long.

The foundation trestle is made by pinning the cap on the top of the legs and spiking or pinning on the braces, as ties to the angles between the cap and legs. The legs should be the same distance apart as the feet of the trussed trestle.

If practicable, the foundation trestle will be put together in position; if not, it must be made on the abutment, and lowered into position by ropes. If the abutment has no batter, the feet of the foundation trestle will be set a few inches out from the masonry.

In placing the trussed trestle, slip it out until the brace comes nearly to the edge of the abutment. Place a flooring pole under and at right angles to the brace, near each end, the butt of the flooring pole projecting about a foot beyond the edge of the abutment. Attach a guy rope to each end of the cap. Slip the trestle out until the brace rests on the projecting ends of the two flooring poles, and revolve the trestle carefully about the brace, while men hold the guy ropes to prevent too rapid rotation. The feet of the trussed trestle will come within 4 inches of the niche in the abutment, or top of the foundation trestle. Raise the ends of the two flooring poles until the feet of the trestle rest on the bed prepared for them. Withdraw the flooring poles. Ease away on the guy ropes until the tops of the trestles meet over the middle of the span. Guide them, so that the 12 foot will fit inside the 13 foot trestle, and they are locked.

Laying the Stringers. — Lay two or three flooring poles from the abutment to the trestle brace, to make a footway. Two men then cross to the trestle from each side. The longitudinal braces are passed to them from the abutments, laid on the braces inside the legs on each side and lashed to the legs and braces.

The girders are then passed over, laid, and lashed, in the angles between the legs and longitudinal braces. The 14 feet stringers are then laid from the abutments to the girders on each side, and the 8 feet stringers across the girders, inside and overlapping the longer ones.

Laying the Flooring. — If the flooring is to be of poles, they will be laid after the style of a corduroy road — the ends being secured by a pole pinned to the outside stringer — and then covered with straw. The bridge is now finished.

The Lashings. — The strength of the bridge depends largely upon the lashings.

This part of the work should be carefully done. To lash one spar to another is a difficult operation. To describe how it is done seems to be worse.

The lashings for the trussed trestle bridge, however, are all alike. To describe one is to describe all. The following description applies to the cap and leg lashings. By changing the names of the spars it will apply to any other.

The cap being laid on the legs, as already described, make a clove hitch round the leg below the cap, carry the rope up in front of the cap, round in rear of the leg and below the clove hitch, up in front of the cap, round in rear of the leg, down in front of the cap, and so on, keeping outside the folds already made on the cap and inside those on the leg, until the necessary strength is attained; then bind the lashing, by taking two turns around it in the angles between the logs, and secure the end by a clove hitch on the cap.

Strength of the Bridge. — The stresses on the various beams may be calculated as in the stringer bridge. In this bridge, however, the whole weight is supported by the four trestle legs. The important question is — "What load can they carry with safety?"

The weight is applied at the middle of each leg and acts in the direction of its length. The question then becomes — "What is the absolute load for a stick of yellow pine of the size and length of the trestle legs?"

Remembering that D = 8 inches, L = 13 feet, and e from the table = .00152, and the formula,

$$D = \sqrt[4]{L^2 w \times 1.7\,e} = 4.36 \text{ inches.}$$

Substituting and reducing gives,

W = Breaking Weight = 9379 lbs.

Deducting fifty per cent. for safety, leaves,

Supporting Power = 4689 lbs.

and for the four legs = 18,756 lbs.

Deducting weight of bridge, nearly = 6000 lbs. leaves —

The service load = 12,756 lbs.

Field artillery at 400 lbs, per lineal foot, or 12,000 lbs. for the whole bridge, is within the limit of safety, and cavalry in column of twos, when crowded by a check, 350 lbs. per lineal foot, is also safe; but infantry, if they pass in column of fours, must be careful to maintain full distance. At full distance infantry weighs 225 lbs. per lineal foot — well within the limits; but a check in the column, and the consequent crowding, more than doubles the weight and carries them beyond the limit. Infantry therefore should be required to cross in column of twos.

Trestle Bridges.

Upon streams with hard bottoms, and velocities not exceeding 6 feet per second, trestle bridges are much resorted to in America. They possess many features which recommend them to the military engineer, not only for the improvised bridges built by armies in pursuit, but also for the more substantial structures erected on lines of communication.

There are many kinds of trestles — each claiming special merits for itself — in use by civil and military engineers. Only those adapted to the military service in this country, will be described here.

To meet the requirements of the military service, a trestle should be strong enough to sustain the artillery and baggage trains of the army, simple enough to be constructed by the labor of the troops out of rough round sticks, and capable of ready adjustment to irregularities of bottom.

Among many which meet these requirements may be mentioned: —

The Six Legged Trestle. — This trestle can be made of round logs, by soldier labor, and will adapt itself to almost any irregularity of bottom.

It is composed of —

4 Vertical legs, 6 inches in diameter.
2 Bracing legs, 6 inches in diameter.
1 Cap or girder, 8 inches in diameter and 12 feet long.
2 Foot pieces, 8 inches in diameter and 3 feet long.
10 White oak pins, 3 inches in diameter.

There are no tools required, except those usually carried with troops, namely, axes and augers, and some rope.

For raising the trestles, two sliding beams 8 inches in diameter and at least twice the length of the span, four short rollers — sections of logs — two 12 inches in diameter, and two 6 inches, will also be required. These can be procured from the woods.

Making the Trestle. — Soundings having been taken along each side of the proposed bridge, the lengths of legs of the several trestles having been determined, and material procured, the men proceed to make the first trestle.

Selecting some level spot near the water, from which the prepared trestle can be readily launched, a framing platform is constructed. The framing platform consists of two logs, parallel to each other, and the width of the bridge apart, laid with an inclination of perhaps 30° towards the water to facilitate the launching of the finished trestle. The upper face of the platform logs should be hewed. They are designated *right* and *left* with reference to the trestle legs as they lie on the platform, to minimize the chances of error in constructing trestles with unequal legs.

Having received instruction as to the lengths of the right and left legs of the first trestle, the makers lay logs of the requisite length on the proper sides of the plat-

form. The cap piece is laid across at the height of the roadway, the foot pieces across the feet of the trestles. The other two vertical legs are then laid on the top, resting on the cap and foot pieces, and four auger men bore through the three logs at each corner. Pins are then driven, and, if necessary, wedged, and the bracing legs pinned to the foot pieces. The trestle is then launched, and towed or poled into position for hoisting.

Meantime, preparations for hoisting have been going on. The sliding beams have been advanced, one on each side of the road, until their front ends are over the position of the first trestle, the large roller in front a very little in advance of the center of gravity of the beam, the small roller in rear.

If there be much current, some provision should be made to hold the trestle, for the few seconds necessary to adjust the slings and raise it into a standing position.

The trestle is brought abreast of the bridge-head, the cap towards the bridge, and as near its proper position as practicable.

Raising the Trestle. — The sliding beams are lowered, by raising their ends until they nearly touch the water; short slings are passed around the ends of the sliding-beams. The trestle is then raised slowly, by lowering the rear end of the sliding beams, until it hangs directly over its place. It is then allowed to drop into position by raising the rear ends of the sliding beams, the side stringers are slipped across the span and secured, the bracing legs are driven into place and pinned, short pieces are spiked or pinned across the vertical legs under the ends of the cap piece as supports, and the trestle is placed and finished.

Laying the stringers and flooring are as heretofore described.

Note. — If, on account of the length of the sling used, it be found impossible at the first lift to raise the trestle's feet off the bottom, let it rest, and shorten the sling; or, if necessary, place the ends of the sliding beams under the trestle cap for a fresh lift.

The Tie Block Trestle. — The peculiarity of this trestle is, that the cap is held in position, not by being spiked, or pinned, or lashed to the legs, but by pinching them. The cap consists of two pieces, one on each side of the legs, held together by four tie blocks, two spiked into notches on the upper side of the cap pieces and inside the legs, and two similarly spiked on the under side of the cap pieces and outside the legs, in such a way, that while the legs are parallel, the cap can be moved freely up and down, but, when the tops of the legs are pulled together by a sling and rack pin the legs are pinched by the tie blocks, so as to be able to sustain the roadway without any other fastening. When placed, the legs are tied to the cap pieces by short braces, and the sling and rack pin removed.

The material required for each trestle would be —

2 Legs, 8″ in diameter.
2 Caps, 8″ in diameter and 15 feet long.
4 Tie blocks, 5″ x 6″ and 2 feet long.

24 Spikes.
2 Braces, 2″ x 6″ and 3 feet long.

The tools and implements required would be —

Axes.
Hatchets.
Cross-cut saw.
2 Guide blocks, 8″ in diameter and 12″ long.
1 Rope sling and rack pin, — Sling 11 feet long.

To make the Trestle. — Lay the cap pieces on the framing platform, the guide blocks on end between the pieces and about 15 inches from their ends. Lay a tie block across the cap pieces at each end, outside and close to the guide blocks, and mark their positions. Cut notches — 2½ inches deep — for the tie blocks, in conformity with the marks. Spike on the tie blocks. Turn the cap pieces over. Place the guide blocks in position as before. Lay two or more tie blocks on the cap pieces, this time inside the guide blocks. Mark and saw out the notches, and spike on the tie blocks.

Pass the legs through the openings enclosed between the cap pieces and tie blocks at each end, until the length of each, below the cap, corresponds to the length required by the soundings. Pass the rope sling over the tops of the legs and tighten, by means of the rack pin, sufficiently to hold the trestle in position. Launch, and float to place.

Placing the Trestle. — This may be done exactly as in the case of the six legged trestle. When it stands in position, if the cap pieces be horizontal and the right height above the water, the top of the legs are braced tight by turning the racking pin, and the braces spiked on across the angle between the cap and upper leg. The sling and racking pin can then be removed.

If the cap piece is not horizontal when the trestle stands in position, the low end can be knocked up by striking it below. If it is too low, both ends can be thus raised. If it is too high, slacken the sling and knock it down. When it is right, tighten the sling hard, spike on the braces, and remove the sling.

Placing the stringers and laying the flooring need no special description.

Paine's Trestle Bridge. — Where a stream intercepts the march of a detachment, not on the main line of advance, and it is desired simply to get the detachment across, in as short a time, and with as little labor as possible, resort may be had, with advantage, to what is known as Paine's Bridge, provided timber be abundant, and the stream not over 6 feet deep.

To build the Bridge. — Select suitable trees up stream. Fell them into the stream and trim off their branches. Bore two 3″ auger holes near the butt end of the log, about 3 inches apart and making an angle of about 30° with each other. This can be done while the tree is being felled. Cut, trim, and insert in the holes, legs of sufficient length to raise the butt of the log the desired distance out of the

water. Pass a rope once around the butt, and make fast to one of the legs. Float down the stream, butt end first, to the position of the proposed bridge.

When the butt end of the log has arrived on the line of the bridge, the end of the rope is thrown to parties on the shore, who sieze and haul upon it until the log is turned on its feet. The effect of this, and the action of the current, is to sink the top end of the tree and keep it on the bottom. A bracing leg is then prepared, its foot set down stream so as to give it an inclination of about 45°, and its top driven hard between the two legs already in position.

Log after log is thus placed, until these improvised trestles reach across the stream. Meantime stringer logs have been cut, floated down stream side ways, and rolled up the incline of the trestle logs into position — the smallest being placed on the upper, the largest on the lower side to level the roadway.

Flooring poles are laid in the usual way.

The Crib-Abutment Bridge.

Where the streams are sluggish, with muddy bottoms, and not more than 6 feet deep, as are many of the rivers and bayous of the South, and with timber abundant and convenient, the best and speediest bridge construction is the crib abutment.

The depth of the stream having been ascertained on the line of the proposed bridge, a section is drawn roughly, showing the positions of the proposed abutments, their heights below water, and the height of the proposed bridge above water. From these data the bridge is constructed.

The abutments are built in the woods, a party of axemen being set to work upon each. The foundation logs of each abutment are pinned together, the others simply notched together after the fashion of a log house, only the notches are no deeper than is necessary to secure their position in the saddle. When the abutments have reached the desired height, the logs are carefully marked, taken down, carried or floated to their positions — foundation logs first — and rebuilt.

As a rule no difficulty will be experienced in rebuilding the cribs. Poles are generally set in the mud to mark the four corners of the crib. The foundation logs are put together and pinned inside these guides. The second, third, and fourth tiers, etc., are then laid on, the crib sinking gradually until the foundation logs rest on the bottom. If the logs are not exactly horizontal when the crib reaches the top of the water, a few blows of an axe on the saddle, or in the notch, of the logs on the high side, will correct the error, and the abutment is then completed.

The stringers can be placed, and the flooring laid in the usual way.

The special advantage of this kind of bridge is, that work can go on simultaneously on all the cribs, and every American soldier will understand its construction.

Pile Bridges.

Pile bridges can hardly be considered improvised structures. Their erection

requires an amount of preparation hardly consistent with emergency, so they are rarely resorted to by armies or detachments in pursuit. For bridges on lines of communication however, the character of the bottom, or the dangers from ice or drift wood, sometimes compels a resort to this kind of structure.

Building a bridge on piles, after the piles have been driven, involves no new problem. A row of piles with their cap on, being practically a placed trestle, the roadway will be laid as already described. Pile driving however is a new operation.

Military Pile Driving.

Where a regular pile driver can be obtained, it will, of course, be used. We are not justified however in assuming the presence of such a machine at the time and place where it is most wanted by an army. The military engineer must know how to drive piles without it. There are several ways of doing this, the simplest and best being by means of a rammer.

A rammer — is a block of wood, about 3 feet long and 12 inches in diameter, having four pins or handles on the top, and four on the sides. It is operated by four men, who stand on what is called a driving platform fitted on the top of the pile, thus adding their own weight to their efforts with the rammer.

The Driving Platform — consists of two pieces of 2-inch plank, fastened together at right angles to each other, and having a square hole in the middle which fits upon the head of the pile. In the preparation of the pile on shore, its head is carefully squared for a distance of 12 inches, terminating in a shoulder. The driving platform fits upon the square head and rests upon the shoulder of the pile. It is provided with a rope ladder by which the drivers mount the platform.

The Raft or Float. — Piles for a bridge are driven in rows, crosswise the bridge. To facilitate the operation, rafts or floats are constructed of the available bridge material, such as stringers and flooring. These rafts should be of a width equal to the distance between rows of piles, so that when made fast to a row already driven the opposite side of the raft will mark the position of the next row. Three or four piles constitute a row. They should be driven simultaneously. There should therefore be from 18 to 24 men on each raft.

Two rafts will generally work together. While one attends upon the party driving the piles, the other is being moved by its party for the next row.

To facilitate the mooring of the rafts, a rope is stretched across the stream above the line of the bridge, anchored and floated at intervals if the stream be a wide one, to which the floats are made fast and hauled into position.

Pile driving can begin at several points along the line of bridge. Guided by the rope above mentioned there can be no difficulty about this. The worst error possible would be a longer or shorter span at the junction of sections which would not effect the strength of the bridge.

The operations are : —

1. Procuring Material.
2. Preparing the Piles.
3. Transporting and erecting the Piles.
4. Driving the Piles.
5. Capping the Piles.
6. Laying the Roadway.

Procuring Material. — The method of organizing this part of the work has already been discussed in the section on Railway Trestle Bridges, p. 2, et seq. The same principles will be observed.

Preparing the Piles — that is, sharpening the points and squaring the heads for the driving platform. The work should be done at some point near to, and above the bridge, affording facilities for launching the piles. Good axemen will be required. They should be provided with a pattern driving-platform to guage the pile heads by.

Transporting the Piles. — Piles should be rafted to the bridge, the number required for one row being united in a raft. Two men will be enough to navigate the raft. The drivers will assist in erecting the piles on their arrival, and the navigators will find their way back for another raft.

Driving the Piles. — Six men are required to each pile. The head of the pile is lifted on the raft. The driving-platform is fitted on. The pile is then pulled up until it assumes a vertical position. It is then dropped, two of the six men holding it, while the remaining four mount upon the driving-platform, sending up the rammer before the last two men mount. The pile is then driven.

Capping the Piles. — Strips of board are nailed across each row of piles, and plank scaffolding thrown across. The pile heads are then sawed off level, the cap rolled across on temporary skids, placed on the top of the row of piles, and pinned or otherwise secured.

Laying the Roadway. — As the floats become of no further use they are broken up and worked into the roadway.

Bridges on Rafts.

A common expedient for crossing rivers in Europe has always been the raft bridge, and there is no reason why it should not be common in America. Where rivers are deep, with muddy bottoms, low velocities, and well timbered banks, this kind of bridge might be profitably resorted to. The value of such a bridge, as a matter of course, depends upon the buoyancy of the timber of which it is composed. The engineer must satisfy himself upon that point before proceeding with the bridge.

Buoyancy of Timber. — Timber must be lighter than water before it will float. Fresh water weighs 1000 ounces per cubic foot. Timber to be suitable for a raft bridge should not weigh over half as much. Any text book on construction or pocket

book for engineers contains the weights of different kinds of timber and may be consulted on the subject. These tables, however, are not always reliable guides. There are so many varieties of the same species of tree differing so widely in weight, besides the undeterminable difference between green wood and dry, spring cut, summer cut, and winter cut, that even experts are liable to be deceived. The better way undoubtedly, is for the engineer to determine the buoyancy for himself. If he be without the means of doing so accurately, he can make a sufficiently close approximation, for his purpose, and have the assurance that the error is on the safe side.

To determine the Buoyancy. — Select a sound and symmetrical specimen of the timber not too large for easy handling. Weigh it, and then place it in the water and load it almost to the sinking point — the nearer the sinking point the nearer the truth. The weights required represent the buoyancy of the specimen. Then : —

The Weight of the Specimen : Its Buoyancy :: Weight of any Log : Its Buoyancy.

$$\text{or, Buoyancy of Log} = \frac{\text{Buoyancy of Specimen} \times \text{Weight of Log.}}{\text{Weight of Specimen.}}$$

The weight of a cubic foot of the timber can be deduced from the weight of the specimen, and its cubic contents. The weight of the log can then be readily determined, and by substitution in the above formula and reduction, the buoyancy of the log.

If the logs are not of like dimensions, it may be necessary to calculate the contents of each and work out its individual buoyancy. As a rule, however, the logs will be practically of equal size, and, by selecting as a sample log, one under, rather than over the average, only one need be calculated.

The Roadway — should be as light as possible consistent with strength. If sawed timber cannot be procured, then 6-inch poles for stringers, and 4-inch for flooring. The stringers should rest squarely on two floats from out to out : that is, if the rafts consist of 8 logs, one foot in diameter, and are moored at a distance of 12 feet from center to center, the stringers should be 20 feet long. Each stringer would thus cover two rafts and the intervening space of 4 feet. Four stringers are required. The roadway need not be wider than 9 feet.

The weight of the Roadway. — Assuming that the material is Virginia pitch pine, which is rated in the tables as weighing 35 lbs. per cubic foot, the weight of the stringers would be —

$(.25 \times .7854) \times 4 \times 36 \times 35 = 989.45$ say,	= 1000 lbs.
The weight of the flooring would be — for 50 poles, 9 feet long and 4 inches in diameter	= 1650 lbs.
Total weight of roadway	= 2650 lbs.

Field artillery weighs 400 lbs. per lineal foot or for 12 feet, the length of one bay	= 4800 lbs.
Total weight to be sustained	= 7450 lbs.

Supposing the material is Virginia pitch pine, and the logs average 12 inches in diameter and 30 feet long, and assuming that 35 lbs. as given in the tables, is the correct weight of a cubic foot of such timber, the buoyancy of a cubic foot would be $62.5 - 35 = 27.5$ lbs.

The buoyancy of a single log would be —

$$(1 \times .7854) \times 30 \times 27.5 = 678 \text{ lbs.}$$

And of 16 logs, two rafts = 10.848 lbs. which would give a margin of safety of 3.398 lbs. to the artillery.

Infantry could safely pass over such a bridge, in column of fours, and would be well within the limits of safety even when crowded by a check, but cavalry should cross in column of twos.

Cutting and Carrying the Timber. — The engineer having examined the available timber, determined its buoyancy, and calculated the size of raft and dimensions of logs required, furnishes the officer in charge of the axemen with the bill of timber. This should specify the number, size, and kind of log required for rafts, and the number, size and kind required for stringers and flooring. In cutting raft timber, the size specified should be considered the minimum, in cutting timber for the roadway the size specified is the maximum. While it should be the endeavor to provide timber exactly according to the specifications, when that is impossible the nearest approximation in the directions just mentioned will be taken. If possible, the timber should be procured up stream, and rafted.

Making the Rafts. — This should be done in the water. If the logs are large, and only one layer is required, they are laid side by side, the big and small ends alternating, and secured by poles pinned across near the ends. If the logs are small, the rafts are built up of several layers — the logs of each layer being laid at right angles to those of the layer on which it rests — and all pinned or lashed together.

Laying the Roadway. — The stringers are laid so as to rest on two rafts, overlapping the width of a raft at each end. This distributes the load evenly over two rafts wherever it is applied, and adds to the stiffness of the bridge.

Anchorage.

Not the least difficulty in the construction of a raft bridge is its anchorage. Ropes are indispensible for this, and if they are not carried with the army, and cannot be found in the country, they must be improvised.

Ropes. — Italian hemp ropes are considered the strongest, although manilla

when dry, will sustain almost an equal weight. The breaking weight of good hemp rope in tons is about *one third the square of its circumference in inches.* Taking Italian hemp as the standard, and calling it unity, the strength of manilla would be represented by .9 and green hide .5

Improvised Rope. — Green hide cordage can generally be improvised by an army. The hides of cattle killed for daily consumption are cut up, each into one long narrow strip. These can be plaited together for the required strength.

Sheerline Anchorage. — When the river is less than 100 yards wide, and the current under 4 miles an hour, the rafts may be anchored to a sheerline stretched across the stream. The advantage of this system is, that trees or pile moorings on shore can be resorted to for securing the cable.

Pile Moorings — consist of a row of piles — three or four — driven obliquely behind each other so as to offer a maximum resistance to the strain of the cable. They are driven about 10 feet apart, and project 5 or 6 feet above ground, the top of each pile being tied by a diagonal brace to the bottom of the one immediately behind it.

Velocity of Current. — An important question in connection with bridge anchorage is the force of the current, which, in the case of rafts, depends on surface velocity. This will be greatest in the middle. It can hardly be expected that means will be at hand to determine the velocity with absolute accuracy. Approximate accuracy can be attained by timing the passage of floating bodies at two points whose distance is known. To make a raft bridge practicable, the velocity should not exceed 4 miles an hour.

Improvised Anchors. — While as much of the bridge as possible will always be secured to shore anchorage, the middle portion will sometimes have to be fastened to stream anchors; and, as regular anchors will rarely be found at the points where they are wanted for this kind of work, it becomes necessary to improvise substitutes.

This requires ingenuity rather than education. Rules cannot be laid down in advance suitable to all circumstances. One thing, however, must be constantly kept in mind — *the anchorage is the most important part of the bridge.*

A Boulder — by the addition of a ring bolt, makes a capital anchor, and can, if there is an available boulder, be very readily improvised. The ring bolt can be made on the spot and fitted and fastened into a hole bored in the boulder, by means of molten lead or wedges, in a very short time. The refinement, which prescribes how to fasten the bolt, so that it can be unshipped and carried along when the army has crossed, recommended in some text books, is rather a waste of ingenuity.

The Spare Wheel Anchor — is a very substantial one to tie to. It consists of two spare wheels fitted on a shank of tough wood, the dish of the wheels in the same direction. The shank of wood passes through the nave boxes and is securely keyed front and rear. After the anchor is placed in position, the intervening space between the wheels is filled with stones. Sometimes, in order to give it a better

hold, the tires and felloes are knocked off the wheels. A better way, however, is to pass rails, longitudinally between the spokes and inside the felloes, so as to form a cradle to confine the stones, and drive stakes vertically in front of the second wheel. The cable is attached to the end of the shank.

The Fisherman's Anchor — is an ingenious contrivance and has considerable holding power, but is not superior to the spare-wheel anchor. It is, in fact, a large, rough, wooden grapnel, of the same pattern as the small iron grapnel generally used as a boat anchor. It is made by letting two pieces of tough wood, of the proper size and shape, into each other at the middle at right angles, and pinning fast. The pieces should be bow shaped, so that when pinned together they look like the four ribs of a monster basket. This is the head of the grapnel. The shank consists of four pieces, fitted and wedged into auger holes in the arms of the grapnel. They are united and lashed together, and a loop made for the cable some six or eight feet from the head. Before being lowered into position a big stone is placed within the arms.

An old wheel with the tire and felloes knocked off would be a capital foundation for a fisherman's anchor. By passing a shank of wood through the nave box, bracing the spokes to the shank in some way, and giving it a few stones to hug, an anchor of great holding power will be the result.

Length of Cables. — The anchoring cables should be, at least ten, times the depth of the stream in length.

Rafts of Casks or Barrels.

The more buoyant the material of which a bridge is composed, the greater will be its carrying capacity. That casks and barrels are admirable material needs no demonstration, and, where they are available, they will be used in preference to any less buoyant material.

The Buoyancy of Casks. — Assuming that a cask can be divided at the bung into two frustums of a cone — which is not strictly true, but sufficiently so for the bridge builder's purpose — its cubic contents can be calculated by the formula

$$\text{Cubic Contents} = \tfrac{1}{3} L \pi (r^2 + R^2 + rR.)$$

$$\text{Where } L = \text{Length of cask.}$$

$$\pi = 3.1416.$$

$$r = \text{Radius of head.}$$

$$R = \text{Radius at bung.}$$

The cubic contents in feet multiplied by 62.5 lbs., will give the displacement, from which the weight of the cask should be deducted for the buoyancy

Knowing the buoyancy of one cask, the number to be united in a raft to sustain any desired weight can be readily calculated.

Constructing the Raft. - - The construction of a raft or float of casks will depend very much upon the available material. Suppose the worst case, that is, the absence of everything except the casks, poles from the woods, and improvised, green hide cordage.

Having determined by calculation the number of casks to be united in a float, take one third the number, and place them transversely on two poles laid on the ground, parallel to each other, and one half the height of a cask apart. The casks to be distributed evenly over a distance equal to the width of the proposed bridge, bungs up. Lay another pair of poles on the top of the casks. Lash them to the first pair, at the ends and between each two casks, and cut off any surplus pole that may project at the ends.

Having made and launched three such floats, unite them by lashing a pole across the ends and middle of three, so as to make a large square raft. When enough such rafts are completed, they can be placed, and the roadway constructed as already prescribed for timber rafts. In placing the rafts, the sides of the barrels should be towards the current.

Flying Bridges.

A boat attached by a cable of sufficient length to an anchor in mid-stream, can be steered so as to be driven across the river and back again to the starting point, by the action of the current alone. Such a contrivance is called a flying bridge.

The motion in translation is the result of the force of the current, modified by the inclination of the keel and the restraint of the rope. Theoretically, it is a maximum when the keel of the boat makes with the direction of the current an angle equal to 54° 44′. Practically, this is true only in the case of the flying ferry. In the case of the ordinary flying bridge it is not true.

The Flying Ferry — is not at all uncommon in America. It consists of a boat — generally a scow — with perpendicular sides, attached by stem and stern lines to a cable stretched across the river. The means of attachment are somewhat peculiar and are called *the travellers.*

The Travellers — are small wheels, grooved on the circumference to fit the cable upon which they ride, being maintained in their position by a counterpoise below, to which the stem and stern lines of the boat are attached. They move freely on the cable.

The Cable — is a substantial rope — preferably a wire rope — stretched across the river from bank to bank, a short distance above the crossing.

It should be as taut as possible, and six or eight feet above the water at its lowest point.

Navigation. — The boat being a double-ender, the terms, bow and stern, will change each trip. Suppose it lying end on at the landing place, the stem and stern

lines taut. To cause it to proceed to the opposite shore, — shove off — it may be necessary to resort to poles — until the boat is in the current. Slack away the stern line, and haul in the bow line until the keel of the boat has an inclination to the direction of the current equal to 54° 44′. The current will now begin to act, the boat will be urged across the stream, and the travellers, moving freely on the cable, will respond to the pull thus given them, and keep abreast of the boat. The momentum acquired in mid-stream will be sufficient to carry the travellers up the incline at the other end of the cable, and land the boat squarely end on.

The Ordinary Flying Bridge. — When the boat is attached by a cable to an anchor in mid stream, and swung by the action of the current to a point on the opposite shore abreast of the starting point, it moves on the arc of a circle. During the first half of its journey it moves to a certain extent with the current. During the last half it moves against it. Manifestly, to obtain the maximum effect from the current, the inclination of the boat must be constantly changing.

On the downward branch of the curve, the boat should be steered so as to take full advantage of the current. The angle of inclination will be greater than the theoretical angle. As it approaches the lowest point of the curve, it should be gradually braced up to the current, passing the middle point at the theoretical angle.

At the middle point the velocity of the boat will be a maximum. On the ascending branch of the curve it should be steered so as to utilize its acquired momentum. The inclination of the keel to the current becomes less and less until the landing is reached. The boat should be steered by a sweep.

The Cable. — The length of the rope should be at least one and a half times the width of the river. The longer the radius the smaller and flatter the arc to be traversed. It should be buoyed up above the water from near the anchorage to the bridge. The usual contrivance for this purpose, in large bridges, consists of boats moored to the cable at intervals, by short painters. These boats have masts amidships — increasing in height, from the anchorage to the bridge — with sheaves let into mortices on their tops, over which the cable passes. In this way, the boats, while they support the cable, are free to accommodate themselves to its angular motion and the current of the river.

The Buoy-Boats. — For very large bridges there will be several buoy-boats. They should be of different sizes, diminishing gradually from the largest near the anchorage to the smallest near the bridge. The largest should have considerable breadth of beam — might be a scow without detriment. It has no mast, and no perceptible motion. The cable is laid over its stem and stern and stretches directly to the bridge in one direction, and to the anchor in the other. It is the principle prop between the anchor and the bridge, and therefore has to sustain a much greater pressure than any of the other buoy-boats.

The other buoy-boats are smaller, in proportion to their distance from the center

of motion. They should be long, deep, and narrow. They are moored to the cable by a painter at the bow, and spring line at the stern, of such length as to allow free play within certain limits. The limits are the maximum and minimum inclination which the boats would naturally assume, under the influence of the current and the angular motion of the cable. Masts forked at the top, instead of being provided with sheaves, will answer every purpose.

The Bridge. — Small bridges may consist of a single boat. The boat should be a double ender, long, narrow, and deep, with vertical sides. Sweeps alone can be depended upon for steering. The cable is attached to the mast, which should be set well forward, not more than one third the length of the boat from the bow.

For large bridges two boats are united so as to form a raft after the fashion of the Catamaran. The distance between boats depends on their length. It should be as great as considerations of safety will permit, the object being to facilitate the free action of the current on the sides of both boats.

The Flying Bridge and Independent Return. — Sometimes the strength or direction of the current, or other circumstance, may make it impossible to stem the current on the ascending branch of the curve to a point abreast of the starting point. In such a case the landing can be made at any convenient point on the opposite shore, and the empty boat pulled up stream the necessary distance, for a flying return.

The Anchorage. — In this case there are two anchorages, one on each side of the stream, opposite to each other. They may be ordinary anchors, mooring stakes, trees, or anything available, but should be, if possible, on some point, natural or artificial, projecting a little distance into the stream.

The Cables. — The cables are attached to the anchors, one on each side, and also made fast to the boat, one at each end. They are a little longer than the width of the stream.

The Navigation. — Being at one side of the river, cable No. 1 extended from the opposite anchorage to the boat, the slack of cable No. 2 coiled in the stern of the boat; to proceed to the other shore: — Cast off. Haul away on cable No. 1. Pay out cable No. 2. When the boat is fairly in the current, make fast cable No. 1. The boat will swing rapidly towards the opposite shore. Steer so as to keep the keel at right angles to the cable. If the boat approaches the landing with more speed than is desirable hold water with a pair of sweeps.

The landing having been effected, and the load discharged, haul away on No. 1 cable coiling the slack as it comes in, until the boat is nearly at the anchorage, — the slack of No. 2 having been also hauled in. Make fast No. 2. Let go No. 1. The boat will then swing back to the hither shore, striking a point a little over the width of the stream, below the anchorage. Haul away on No. 2 up to the starting point.

On the return trip, unless the current is very strong, the hauling on No. 2 cable might be continued during the crossing.

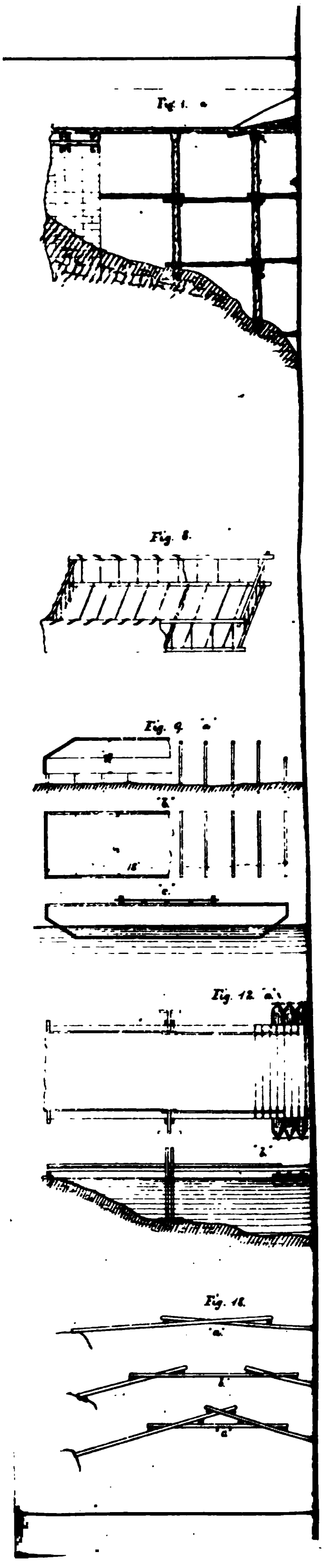
Fig. 1. a
Fig. 8.
Fig. 9. a
b
c
Fig. 12. a
b
Fig. 16.
a
b
c

[illegible]

There are innumerable variations of the flying bridge, all of which are modifications, or combinations of the three types above described.

SECTION 4.

Ponton Bridges.

There are two kinds of Ponton Bridge in the United States Service; namely, the *Reserve-Train Bridge*, and the *Advance-Guard Bridge.*

The Reserve-Train Bridge accompanies the army in its operations. It is a substantial structure, capable of sustaining the heaviest trains of an army, and perfectly safe in the swiftest kind of streams. It is carried, in quantities sufficient to span the widest rivers in the theater of operations.

The Advance-Guard Bridge is a much lighter structure, intended for use with advanced guards, cavalry raids, and similar expeditions.

The Reserve-Train Ponton Bridge — used in the United States Service, is a modification of the French ponton bridge. Its several parts are loaded on wagons, according to a prescribed schedule, each division of the train carrying material for a certain length of bridge. The width of the widest river in the theater of operations determines the number of divisions to accompany the army.

The packing of the wagons and organization of the train, will be described after the component parts of the equipage have been introduced.

The Bridge Material — carried in the train, consists of trestles, abutment sills, pontons, balks, chess, saddle transoms, saddle sills, rack sticks, rack collars, pickets, anchors, cables, lashings, and boat furniture which includes oars, boat hooks, scoop shovels, scoops, and buckets.

The Trestle — is used in the construction of bridges over dry ravines, and in the space between the bank and the first ponton, where the water is shallow. Two are carried with each division of the bridge train.

A trestle consists of 2 legs, 2 false legs, 2 shoes, 2 suspension chains and one cap.

The Legs — are pieces of white pine scantling, 15 feet long, 7 inches broad, and 4½ inches thick. For a few inches at the top they are rounded, the round part terminating in a square shoulder, which supports the ring of the suspension chain. The ring of the suspension chain fits over the rounded top of the legs. At the bottom, they are shaped into tennons pierced by auger holes one inch in diameter, which fit into mortices in the middle of the shoes.

The False Legs — are small pieces of scantling used to lock or wedge the cap at any position on the legs. The holes in the cap being much larger than the legs, the cap can be slipped up or down to any desired position. The false legs are then inserted to fill up the vacant space, and, the tops of the legs being pulled together, the cap is locked.

The Shoes — are intended to prevent sinking in muddy bottoms. They consist,

each, of two pieces of white pine plank 30 inches long, 15 inches wide, and 1½ inches thick, nailed together so as to form a 3-inch plank, and the corners rounded off. A mortice in the middle of the shoe receives the tennon of the bottom of the leg, and the shoe is keyed on, by means of an iron bolt attached to its upper surface by a chain, which is passed through two eye-bolts on the shoe, and the hole in the tennon already mentioned.

The Suspension Chains — are two strong iron chains, 8 feet long, provided at one end with rings to fit over the leg tops, and at the other, with toggles to fit into the rings on the cap. When in position, the tops of the legs incline inward, and the suspension chains hang freely from their tops to the cap, and constitute the principle supports of the roadway.

The Cap — consists of two white-pine planks, 20 feet long, 12 inches wide, and 2 inches thick, fastened to six 3½ inch blocks which separate the planks. Four of these blocks are oak, and two pine. The oak blocks are placed, one inside, and one outside each leg. The pine blocks are inside the inner oak block, and act as skew-backs to a curved piece of pine which is introduced between the planks to increase their strength and stiffness. The cap is, therefore, a trussed arch on a small scale. On the upper side of the cap near the ends, are two eyes which receive the hooks of the suspension chains.

The Abutment Sill — is a piece of white pine, 14 feet long, 8 inches wide and 6 inches thick. It is sunk in the ground at the shore end of the bridge, and secured by four stakes, two in front and two in rear, 8 inches from the ends. It should be laid accurately, at right angles to the axis of the bridge, and so as to be bisected by the axis. The middle of the sill is permanently marked. For convenience in carrying it is provided with rings at the ends.

The Ponton — is a wooden bateau or scow 31 feet long, 5 feet 8 inches broad at the broadest part, and 2 feet 6 inches deep. The frame is of white oak, the planking of pine. The ponton weighs about 1657 lbs., and has a buoyancy of 18,674 lbs. It can carry 40 soldiers in heavy marching order in addition to its crew and equipment, and, in a bridge, has proved itself capable of sustaining the heaviest army trains.

Nomenclature of the Ponton. — The ponton consists of: — The bottom and side timbers, the mooring posts, the battens, the timber plates, the cavil, the bottom planks, the chafing battens, the side planks, the clamp, the plank sheer, the cross braces, the row-locks, the row-lock blocks, and the bow and stern bindings.

The Bottom and Side Timbers. — There are twelve timbers, or ribs, of white oak to each ponton. Those at the ends are 4 by 4, the second from the ends 3 by 3, and the remaining eight 2 by 3 inches. The end timbers extend upwards 10 inches above the plank sheer, and constitute the mooring posts. They are bevelled at the bottom for the bottom plank.

The Mooring Posts — are the continuation upwards of the side timbers at both ends of the ponton. They rise to a height of 10 inches above the gunwale, being rounded for about 6 inches, and terminate in a head 4 inches square.

The Battens — are short strips of pine, 4 inches wide and 1¼ thick, inserted between the bottom timbers to hold them in place.

The Timber Plates — are pieces of iron shaped so as to fit the timbers at the angles between the bottom and sides. They are fastened to the timbers by three rivets and eight screws, one rivet at each end and one at the angle, four screws in the bottom and four in the side timbers.

The Cavils — are pieces of oak, 4 inches wide and 1 inch thick, shouldered ⅝ of an inch into the side timbers, to strengthen them at the points where the lashing hooks are inserted.

The Bottom Planks — are seven in number. They are of pine, 1 inch in thickness, and extend from end to end of the ponton. They are fastened to the timbers by two rivet-headed nails in each, driven clear through and clinched on the inside, and also to the battens in the same way.

The Chafing Battens — are of white oak, 5 inches wide and 1 inch thick. Five of them are fastened longitudinally to the bottom planks, by nails driven through and clinched, and at the ends by screws.

The Side Planks — are of pine, ⅞ of an inch thick, and extend from end to end of the ponton, They are fastened to the timbers in the same way as the bottom planks; and, in addition, the bottoms of the lower ones are nailed to the bottom planks with 10 penny nails.

The Clamp — is a ribbon of pine, 3 inches wide and one inch thick, let into the side timbers at the top, on the inside of the gunwale.

The Plank Sheer — is a piece of oak, or ash, about 5 inches wide and 1 inch thick, nailed on the top of the gunwale with 10 penny nails. The nails are driven at intervals of 5 inches, into the clamp and side planks of the ponton.

The Cross Braces — are pieces of spruce, 9 inches wide and 2 inches thick, fastened by 3 screws at each end to the timbers.

The Row-Locks. — There are 14 row-locks to each ponton. The row-lock plates are let into the plank sheer so as to be flush with its upper surface. The row-lock sockets extend downwards into the row-lock blocks.

The Row-Lock Blocks — are pieces of oak not less than 2 inches in thickness fastened under each row-lock to receive and hold firmly the row-lock socket.

The Bow and Stern Bindings — are continuous bands of iron which pass around the bow and stern of the ponton, so as to bind the ends of the planking. They are fastened on with screws.

The Balks. — There are two kinds of balks in the Reserve-Train Bridge Equipage, namely, the trestle balk, and the long balk.

The Trestle Balk — is of white pine, 21 feet 8 inches long, 5 inches broad, and 5 inches thick. It is provided at each end with two oak cleats forming a claw 8 inches wide. The distance from center to center of the claws is 20 feet. The claws are intended to fit on the trestle caps.

The Long Balk — is also of white pine, 27 feet long, 5 inches broad, and 5 inches thick. It is provided at each end with a cleat of oak, the distance from cleat to cleat being 25 feet 8 inches. The long balk may be laid so as to rest squarely on two pontons, the cleats laying hold of the outside of each. When thus laid, the distance from center to center of adjacent pontons is 20 feet. If saddle transoms and saddle sills are used, the cleats of the long balk lay hold of the saddle sill, and the distance from center to center of adjacent pontons will be 25 feet. The long balk is also used as a side rail.

The Chess — is a name given to the flooring boards. It is the same in the singular and plural. Chess are made of white pine, 13 feet long, 12 inches wide and 1½ inches thick. For a distance of 2 feet from each end they are cut away ¾ of an inch on both sides, leaving those portions only 10½ inches wide. This, when the chess are laid, leaves an opening at the ends, between each pair, of 1½ inches, through which the side rail lashings are passed. The chess are permanently marked at the middle as a guide to the chess layers.

The Saddle Transoms — are pieces of white pine, 5 feet 4 inches long, 4 inches wide, and 8 inches deep, fitted at the ends with strong iron hooks, and having two small cleats at the middle, between which, the sill rests, when in position. They are used in connection with the saddle sill when the long balk is intended to reach only from center to center of adjacent pontons. When such is the desire, the saddle transoms are laid across the ponton, one at each side of the roadway. They rest on the plank sheer, the hooks at their ends laying hold of the outside of the ponton. The saddle sill is then laid in the saddle formed by the two small cleats at the middle of the saddle transom, and constitutes the support for the ends of the long balks.

The Saddle Sills — are pieces of white pine, 14 feet long, 5¾ inches wide, and 8 inches deep. They are used in the manner, and for the purpose, described in last paragraph.

Rack Sticks — are pieces of hickory, 2 feet long and 1¼ inches in diameter having a cord 4 feet long fastened in a hole at one end.

Rack Collars — are loops of strap iron, the long diameter 19 inches, the short 5 inches. They are made in two parts and united by a link at each end.

The Pickets — are of oak or hickory, 3 feet long and 3 inches in diameter, shod at the point and bound at the top with iron.

The Anchors — are kedge anchors weighing 150 lbs. each.

The Cables — are of 3-inch manilla rope, two coils of 40 fathoms each being the outfit for a ponton.

The Lashings — are of 1-inch manilla rope, and 18 feet long.

The Boat Furniture — consists of oars, boat hooks, scoops, and buckets, which need no description.

Construction.

There are four methods of construction practiced in the United States, namely — by ponton, by parts, by rafts, and by conversion. It will only be necessary to describe one of these in detail.

To Construct the Bridge by Pontons.

Preliminaries. — The material is unloaded from the train. The balks are piled on the left near the bridge head, the chess on the right. The pontons are launched equipped, and temporarily moored up stream. The anchors are attached to the cables, and the up-stream ones properly placed in the bows of the pontons. The down-stream cables and anchors are placed on board a special ponton below the bridge, in charge of the down-stream anchor detachment.

Number of Pontoniers. — The number of men required with a ponton train varies with the size and character of the train, and is always large. There is much work to be done in loading and unloading, handling, and carrying material, which, under proper supervision, can be performed by unskilled laborers, or soldiers detailed from the army. In constructing and dismantling the bridge, however, trained pontoniers are indispensible, and only a certain number can be employed at a time, advantageously. When the bridge is extensive, relays of men may be resorted to. Well trained pontoniers can relieve each other at any stage of the construction, without causing confusion or delay.

For a short bridge, requiring no more than one division of the train, the following detail would be required.

SECTION.		NON-COM. OFFICERS.	PRIVATES.
1.	Placing Abutment Sill and lashing Side Rails....	1	4
2.	Casting up-stream Anchors..........................	1	4
3.	Casting down-stream Anchors........................	1	4
4.	Balk carriers	1	10
5.	Lashers..		10
6.	Cable men...		2
7.	Chess carriers and coverers...........................	1	22
	Total...............................	5	56

The above may be considered the unit of organization. For longer bridges, it, or any of its sections, may be doubled or trebled as may appear necessary to insure the steady progress of the construction. It will rarely be necessary to strengthen a section by adding men to it. The better way to help it, is to set another section at the same work.

If the current be strong, the second and third sections may be re-enforced by the addition of men. The unit is calculated on the basis of about two miles an hour velocity of current.

For short bridges, one commissioned officer will be sufficient. For a bridge requiring two or more divisions of the train, three are indispensible: one in command, one at the bridge head, and one superintending the anchorage.

Placing the Abutment Sill. — The proper position for the abutment sill must be accurately determined. It should be at right angles to, and bisected by the axis of the bridge, and horizontal.

While the position of the sill is being determined, Section 1 is employed in preparing the approaches to the bridge, and clearing away everything, as far as practicable, that might impede the work of construction.

The position of the abutment sill having been determined, and staked out by the officer on duty at the bridge head, Section 1 proceeds to dig the trench for the sill. This will be about one foot deep and one wide. The bottom must be horizontal.

The sill is then laid in the trench, its middle mark in the axis of the bridge, and secured in its position by four pickets, two in front and two in rear, within 8 inches of the ends.

When the balks of the abutment bay have been put in position, a chess is placed on edge behind the abutment sill and against the ends of the balks, and earth rammed hard behind it. The upper edge of the chess should be about 1½ inches above the upper surface of the balks.

Placing the First Ponton. — Assuming that there is water enough, the first ponton is brought up close to the bank and opposite the abutment, by Section 2, and mooring pickets are driven — one 30 paces above, and one 30 paces below the bridge — by Section 6, who also attach cables to the mooring posts and carry the free ends to the bridge head.

As soon as the ponton reaches the bank, the men with the cable ends jump on board, one at the bow and the other at the stern, and five lashers — half of the 5th Section — having previously provided themselves with two lashings each, follow and take post by the lashing hooks on the stream side of the ponton. The crew jump ashore and go for another ponton.

Meantime the balk carriers — Section 4 — have brought up 5 balks and stand ready to deliver them. All being ready, the ends of the balks are passed to the 5 lashers in the ponton, and the other 5 who are on shore, step up and receive the shore ends. The stream ends are laid on the gunwale of the ponton, on the stream side, their down-stream edges over the lashing hooks, and the cleats against the outside of the ponton. The lashers afloat then take one turn around the balks and lashing hooks, and hold on.

The lashers on shore now push the ponton off slowly by means of the balks, until

they can engage the cleats on the other ends of the balks on the abutment sill. The balks are then laid, their down-stream edges at the marks on the abutment sill, and the chess, already referred to, put in position and secured.

The two cable men — Section 6 — now give the ponton its proper position by tightening or slackening their cables under the direction of the officer on duty at the bridge head, and then make fast, and are brought ashore by Section 3 in a spare ponton.

The chess carriers and coverers — Section 7 — now commence work. Two men station themselves on the balks facing the abutment, one at each side, receive the chess from the carriers as they are brought up, lay them across the balks, being careful that the middle mark of each is in the axis of the bridge, and press them snugly against those already laid. The flooring is laid to within one foot of the ponton.

Note. — Observe that the lashers afloat are left with their work half finished. This is not an oversight. The balks of adjacent bays overlap each other 6 feet and are secured by the same lashings. The 5 lashers in question must remain in the ponton until the balks for the next bay are put in position, when they complete their work. Meantime, the lashers on shore have jumped into the second ponton and assumed the duties of lashers afloat. The two parties alternate in this way throughout the construction.

Note. — The side rails are not laid until the bay is completely covered with chess, and the coverers have advanced to the next bay. By that time Section 1 has completed its work about the abutment sill and is ready to proceed with laying and lashing the side rails.

Placing the Second Ponton. — Section 2, accompanied by the first cableman, conducts the ponton to the line of up-stream anchors, which is indicated by marks on the shore, and, at a signal from the officer in charge of the anchorage, if there be one, if not, at the command of the non-commissioned officer, casts the anchor. This is done with due regard to interval as well as alignment. The cable is paid out by the first cableman, and the ponton drops down-stream and is pulled alongside the ponton already placed.

Meantime Section 3, accompanied by the second cableman, has cast the down stream anchor from their special ponton at the proper place, and pulled up to the placed ponton, the second cableman bringing the free end of the down-stream cable. The second cableman then jumps on board the ponton about to be placed, carrying the cable end with him, and is followed by 5 lashers with two lashings each.

The crew of the ponton about to be placed now jump on the placed ponton, and proceed to the temporary mooring place up stream for another.

The balk carriers — Section 4 — bring up 5 balks, pass one end to the lashers afloat, and the other to those in the placed ponton. The free ponton is pushed out as before, the balks placed on the down-stream side of those already in position on

the placed ponton, and the lashing completed. The lashers afloat take a turn around the balks and lashing hooks, and hold on as before.

As soon as the position of the second ponton has been assured, the two cable men jumped into the spare ponton, the first is set ashore and rejoins Section 2 and the second accompanies Section 3 to place another down-stream anchor as before.

And so the work goes on until the bridge is complete.

Note. — In this example it is assumed that all the pontons have been launched up-stream. With short bridges, such as require the material from one section only of the bridge train, this is not only practicable but preferable. But with longer bridges, requiring the material from several sections, it may be impracticable on account of the absence of convenient moorings up-stream. In such cases one half of the pontons are launched below and the other above the bridge, and they are brought into position alternately.

Lashings. — The balks of adjacent bays overlap each other 6 feet, and are lashed together and to the lashing hooks at both sides of the ponton, thus adding greatly to the strength and stiffness of the bridge. The same kind of lashings are used for balks and side rails.

Lashing the Balks. — Place the loop of the lashing on the lashing hook. Pass the lashing over the balks and under the hook three times. Take a turn immediately above the hook and secure by a slip knot.

Rack-Lashing the Side Rails. — The side rails are laid on the chess immediately over the outside balks, and overlap the axis of each ponton. They are lashed to the balks at three places, namely, at each end where they overlap, and at the middle of the bay. The lashing is passed three times under the balk, up through the opening between the ends of the chess, and finally through the loop in the end of the lashing, and tied slack in a slip knot. A rack stick is then inserted in the slack, twisted to the desired tautness, and secured by means of the cord in the end.

Note. — The construction above described gives an up-stream and down-stream anchor to each ponton. While this is an excellent arrangement, and gives greater steadiness and security to the bridge than any other, it is seldom resorted to except on tidal rivers where the current sets both ways.

On rapid rivers it will generally be necessary to anchor every ponton up-stream; but on rivers of moderate current, every alternate ponton will be sufficient.

The number of down-stream anchors required, is, of course, less than the up-stream — except on tidal rivers. Generally, one down-stream to two up-stream anchors is deemed sufficient, but no ponton should be anchored down-stream, that is not also anchored up-stream. It is a very dangerous economy to be too sparing in the matter of anchors either up or down-stream. Although the latter, seemingly, have nothing to hold, their presence checks the horizontal swaying occasioned by the passage of troops, which is so dangerous to the stability of the bridge. If anchors are available, a wise officer will use them liberally.

To Dismantle by Pontons.

The material being required on the opposite shore, dismantling begins at the end where construction began. Carriers are in attendance in sufficient numbers to remove the material as fast as it is taken up by the pontoniers. These carriers march in single file and keep to the right.

Men to haul up the pontons and repack the train are also in attendance at their respective posts.

The dismantling operations are : —

1. Remove the side rails, and stow the lashings in the nearest ponton locker. (One-half of Section 1.)

2. Remove the chess. This operation begins, when the first has progressed one bay. (2 men of Section 7. The remaining 20 act as carriers.)

3. Remove the balks and stow the lashings in the nearest ponton locker. (One-half of Section 4. The other half act as carriers.)

4. Detach the shore lines, and coil the cables in the first ponton. (Section 6.)

5. Remove the abutment sill and stakes, and place them in the first ponton. (One-half of Section 1.)

Note. — The first ponton is now pulled alongside the second, by means of the balks, and the cablemen jump on board.

6. Man the first ponton and pull for the other side. (Section 3.) Unmoor the second ponton and pass the cable to the crew. (One-half of Section 6.) The cable man then proceeds to the next ponton.

7. Warp to the anchor, weigh it, and pull for the shore. (Section 2.)

And so the work goes on, Sections 2 and 3 returning as soon as they have transferred their pontons to the care of the men detailed to haul them up.

Note. — In dismantling, Sections 2 and 3 should be doubled, and, if necessary, trebled, the spare men of Section 7 being used for that purpose.

Construction by Parts.

A Part — consists of two bays of bridge, with material for a third on deck. The two bays are complete, except that the chess are not laid within 6 feet of either end, in order that the lashers may have opportunity to do their work in connection with constructing the third bay, which connects the part with the bridge head.

It is doubtful if this method is either more expeditious or more convenient than the method by pontons. It consists simply in constructing two bays of bridge at the bank, loading the part thus formed with the material necessary for a third bay, navigating it to the anchor line, casting the anchor and dropping down to its place in the bridge.

The abutment bay is constructed, exactly as in the method by pontons, and the part is boomed out and constructed as if it were a single ponton, the material car-

ried on the part being used. The down-stream anchors are cast where they are deemed necessary, by special pontons.

Dismantling by Parts.

Dismantling by parts is simply construction by parts reversed. The bridge is broken, by taking up the connecting bays, loading the material on the parts thus formed, warping up to, weighing the anchors, and pulling for the shore. The down-stream anchors are recovered by special pontons.

Construction by Rafts.

Construction by rafts is very similar to construction by parts. The rafts consist of two complete bays of bridge. They carry no extra material, except 2 false balks, and 4 rack collars and wedges.

False Balks — are of white pine, 6 feet 9 inches long, 5 inches wide, and 5 inches deep. Rack collars have already been described.

In this construction, the abutment bay is built as before. The rafts are constructed at the bank, navigated to the up-stream anchor line, and the anchor cast. They are then permitted to drop down to the bridge head, are brought alongside the placed ponton, lashed to it, stem and stern, and secured by means of the false balks and rack collars.

The false balks are used in splicing the side rails of the abutment bay to the side rails of the raft. They are laid on the side rails at the joints, and are embraced by two racking collars — one on each side of the joint — on both sides of the roadway. Wedges are then driven between the false balks and the racking collars, and the splice is complete.

Down-stream anchors are cast where they are needed, as before.

Note. — False balks are not carried with the bridge train. They can be made, readily enough, when they are wanted, or trestle balks may be used.

Dismantling by Rafts.

Knock out the wedges and remove the false balks, warp up to and weigh the anchors, and navigate to the shore.

Construction by Conversion.

This method is rarely resorted to. It consists in constructing the bridge parallel to the bank, and up-stream, then wheeling it with the current into position.

The exact width of the river at the point to be bridged must be known. The bridge is then constructed along the bank, with the exception of the bay on the enemy's side, the material for which is loaded on the last bay but one. An extra

ponton is lashed to the last one in the bridge. It carries the abutment sill and bay for the enemy's side, also the necessary mooring material.

Before commencing the wheel, the up-stream anchors are deposited in the bows of the pontons ready for casting, about 15 yards of their cables coiled, the remainder stretched along the bridge. Spring lines connecting the bows and sterns of all the pontons are hauled taut. These lines extend the whole length of the bridge, and a considerable amount of slack is coiled on the first and last ponton.

All these preparations should be made at some point up-stream, concealed from the enemy. Behind an island in possession of the assailant, or, up a convenient tributary on the assailant's side, are good places for the purpose.

Two strong pickets for the spring lines should be planted at the bridge head, and the material for the abutment bay collected on the ground, before the movement begins. This can be done, and should be done, without alarming the enemy, or in any way disclosing the assailant's purpose. If necessary, it should be done at night.

Everything being ready, the bridge is manned. The pontons are occupied by their crews, two men at the bow and two at the stern, with boat-hooks and oars to retard or accelerate their motion and maintain the alignment during the wheel. Cable men are stationed by the up-stream anchors, ready to cast. Sometimes the bridge is loaded with as many men under arms as it can conveniently carry. These are the guards, and should spring ashore as soon as possible on the enemy's side, and cover the bridge head.

At the abutment on the assailant's side, a detachment is stationed to attend to the spring lines, and also prevent the pivot flank from being crowded on the shore and crushed.

A foggy day, or the hour before dawn, is the best time for throwing the bridge. It is cast loose from its moorings up-stream, pushed into the current, and permitted to float down close to the assailant's side. As the point where the bridge is to be established is approached, the wheeling flank is pushed more into the stream, and the wheel begins. When the pivot arrives near the first abutment, the bridge should be at about the angle of 45° to the current.

The spring lines are thrown to the men on the abutment, who take several turns around the mooring posts previously established, easing off a little when it becomes necessary. Others of the abutment detachment with boat-hooks, fend off the pivot ponton.

The cable men are now on the alert along the whole line. The anchors nearest the pivot will be first cast, then the others towards the wheeling flank as they arrive on the anchor line. The cable men then pay out cable until their pontons arrive on the line of the bridge, when they make fast.

As soon as the spring lines are made fast on the assailant's side, the abutment sill and bay are put in position, so also on the side of the enemy. The guard then

jump ashore, down-stream anchors are cast, side-rail lashings at both ends are attended to, and the bridge is complete.

Dismantling by Conversion.

This manœuvre is never resorted to, except in cases of emergency, when an army is closely pursued. It is executed as follows: —

The abutment bays are taken up, the down-stream cables are cast loose and buoyed, the up-stream cables are lengthened, by attaching to each an extra coil or two of rope. The wheel is then commenced by slacking off on the up-stream cables, being careful to maintain the alignment. Meantime, a cable of sufficient length has been attached to the second ponton from the wheeling flank, and the free end carried to the shore towards which the wheel is to be made, and some distance below the abutment, where a detachment takes charge of it.

When the wheel is about half executed, the action of the current on the bridge will tend to drive it obliquely towards the bank it has left, and the strain on the down-stream spring line will become excessive. To counteract this by means of the oars, is the duty of the crews; and, to get the bridge past the danger point as rapidly as possible is the duty of the detachment on shore. The latter haul away lustily on the cable until the wheeling flank is past the middle of the stream, the spring lines are then cast off, the pivot flank pulled or poled out from the bank, the shore cable slacked off, gently at first, then more rapidly, and when the bridge is nearly in the line of the current, cast off entirely. The bridge is then navigated down stream to some sheltered spot behind an island, where it is dismantled.

The anchors and cables are recovered by spare pontons.

The Abutment Bay.

The construction of the abutment bay, already described, is not applicable in all cases. It assumes that the water in the river will maintain the same level while the bridge is in use, also that a ponton can be floated within 20 feet of the bank. These conditions do not always exist. Where they do not, special constructions for the abutment bay must be resorted to.

On Tidal Rivers — the abutment bay must be constructed so as to accommodate itself to the rise and fall of the tide. This is accomplished as follows: —

The first ponton is brought up in the usual way. Saddle transoms are laid across from gunwale to gunwale, 5 inches inside the outer lashing hooks. The saddle sill is laid in the saddles formed by the cleats at the middle of the transoms. Seven trestle balks are then laid from the saddle sill to the abutment sill, and five long balks from the saddle sill to the second ponton. On the second ponton the balks are lashed in the usual way.

The chess are then laid — snugly if it be high tide, loosely if low tide — and the

side rails placed and lashed. The side rails should not lap over the first ponton, but merely meet over the saddle sill, at high water.

By this arrangement, the abutment bay is provided with the equivalent of a hinge, and can accommodate itself to the rise and fall of the tide without straining the balks or side rails.

Where the bridge is exposed to the swell of the tide at the mouths of tidal rivers, it may be necessary to continue this construction throughout, in order that the bridge may be free to undulate in the direction of its length.

When a Ponton cannot be Floated within 20 feet of a Bank — a trestle must be interposed. The trestle may be put together on a ponton, its feet towards the shore. The ponton is then brought up opposite the abutment, ropes are attached to the tops of the trestle legs, or to the cap, and the free ends thrown to men on the abutment. The ponton is pulled in shore as far as it will float, the trestle is slipped out until its feet are over their proper position. They are then permitted to drop in the water, and the trestle is hauled into an upright position by the men on the abutment.

If the water is too shallow to float a ponton, it is not too deep to wade, and wet feet will not be allowed to stand in the way of the construction. If several trestles are required, and pontons cannot be used, they may be placed by men standing in the water.

Re-enforcing Balks. — Balks resting on trestles or any rigid supports, have not the same strength as when supported on floats. In order, therefore, that the trestle bays should have the same strength as the ponton bays, it is necessary to re-enforce the former. This is done by introducing two extra balks. One of these is laid between the first and second touching the second at one end, the other between the fourth and fifth touching the fourth.

The Reserve Bridge Equipage.

The Reserve Equipage — is divided into trains, the trains into divisions, the divisions into sections.

Sections are of two kinds, Ponton Sections and Abutment Sections.

The Ponton Section consists of 3 ponton wagons and 1 chess wagon.

The Abutment Section consists of 1 ponton wagon, 1 chess wagon, and 1 trestle wagon.

The Division is the unit of the equipage. It is complete in itself, and consists of 4 sections, two of which are ponton sections, and two abutment sections. It therefore contains 14 wagons, namely —

8 Ponton Wagons.
4 Chess Wagons.
2 Trestle Wagons.

In addition, it has a tool wagon, and a traveling forge.

A division carries material for 11 bays: that is, 225 feet of bridge, 7 of which are ponton bays, 2 abutment bays, and 2 trestle bays.

The Train consists of 4 divisions, and therefore carries material for 1000 feet of bridge.

The Ponton Wagon — is simply the running gear of an army wagon with a longer coupling, arranged so that it can be readily uncoupled in front, and provided with front and rear bolsters and side stakes.

The Front Bolster — is provided with seven dowels projecting upwards from its upper surface, which fit into corresponding holes in the ends of the long balks when they are loaded on the wagon.

The Side Stakes — are of iron. They project upwards from the ends of the bolsters, front and rear, are about two feet in height, and terminate in rings to which the ponton is lashed when loaded.

The Chess Wagon — is similar to the ponton wagon, except that it is shorter coupled, and has longer side stakes, which can be connected over the load by means of chains, thus binding the load.

The Abutment Wagon -- is precisely the same as the ponton wagon.

Loads.

Load of the Ponton Wagon. — The ponton wagon carries 7 long balks, 1 ponton, 1 anchor, 1 cable, 5 oars, 2 boat hooks, 20 lashings, 6 rack sticks, 1 scoop shovel, 2 small scoops, 1 axe, 1 hatchet, 1 bucket and 20 lbs. of spun yarn.

Stowage of the Load. — The load is stowed as follows: — The 7 long balks are placed side by side between the side rails, the dowels on the front bolster fitting into the corresponding holes in the ends of the balks. The ponton rests on the long balks, stern foremost, the stern rings about 15 inches in advance of the front axle. The rings on the sides of the ponton are lashed to the rings of the side stakes. The anchor is carried under the wagon, over the rear axle. It is inserted from the rear and lashed to the axle. The cable, oars, and boat hooks, are in the ponton, and the axe in the slings provided for it on the rear axle. The small articles are carried in the ponton locker, the bucket in the ponton.

Load of the Chess Wagon. — The chess wagon carries 60 chess and 2 saddle transoms. The chess are packed on edge in layers. The first, consisting of 30 chess, rests on the front and rear bolsters, the shoulders of the notches abutting against the rear bolster. The two saddle transoms rest on the upper notches of the first layer of chess, one in front and one in rear. The second layer of 30 chess, on edge, rests on the saddle transoms, and the whole is secured by fastening the chains of the side stakes across the load.

Load of the Abutment Wagon. — The abutment wagon is loaded with 7 long balks placed as described in the load of the ponton wagon; 7 short balks, and 2 abutment sills as second layer, and the component parts of a trestle as third layer.

In addition, 2 coils of 3 inch rope. The component parts of the trestles are packed as follows: — The false legs are inserted in the holes in the cap, and the legs lashed to the sides so as to prevent them from falling out. The shoes are strung on the suspension chains — the latter pass through the rings on the cap, and are lashed to the rings on the side stakes of the wagon, thus binding the load.

Load of the Tool Wagon. — The tool wagon carries, 30 axes, 40 shovels, 4 spades, 15 picks, 20 hatchets, 4 broad axes, 4 adzes, 2 crow-bars, 10 augers, 2 cross-cut saws, 4 hand saws, 10 tin lanterns, 1 monkey wrench, 1 sledge, 1 grind stone, 1 coil of wire, 1 coil of 3″ rope, 1 coil of 1″ rope, 30 lbs. of iron, assorted, chalk and chalk lines, 50 lbs. of spikes, 100 lbs. of 10-penny nails, 2 block-and-tackle sets, screws, twine, canvas, spun yarn, and needles. These are packed in boxes according to a schedule prescribed by the Engineer Department. The tool wagon is to the pontonier what the battery wagon is to the artillery man.

Note. — The contents of the tool wagon are given in detail, as the best way of imparting a general idea of their character. It is not necessary to memorize the list.

The Travelling Forge — is identical with that furnished by the Ordnance Department, and known as Forge A.

Packing after Dismantling — is a simple enough operation when the loads of the several wagons are known. Sections of men, under proper supervision, are assigned to the different kinds of wagon, and the packing progresses simultaneously. The only difficult operation is loading the ponton on its wagon. This can be accomplished in a variety of ways. The 7 long balks having been loaded, the pontoniers may proceed as follows: —

1. If the nature of the river bottom admits of it, the ponton wagon is backed into the stream until the ponton can be floated into place. It will be necessary, of course, to lash down the long balks.

2. If two large casks can be procured, they are placed under the ponton. This raises it above the level of the wagon bed. The wagon is backed to the stern, and in prolongation of the ponton, the wheels are chocked, and the ponton is run forward, the casks acting as rollers, until it shows an inclination to tip towards the wagon bed. Rack sticks are then laid as rollers on the wagon bed, the ponton run into position, the rack sticks removed, and the ponton secured. The wagon bed is composed of the 7 long balks first loaded.

3. The wagon is uncoupled, and the front part lowered to the ground in front of, and in prolongation of the ponton. The rack sticks are laid on the wagon bed, the ponton urged up the incline until it is nearly balanced on the rear axle. The rollers are then chocked, the wagon limbered up, the position of the ponton rectified, the rollers removed, and the ponton secured.

4. Holes are dug for the hind wheels, deep enough to bring the ends of the long balks to the level of the ground. The wagon is backed into these and the ponton run up and secured as in last case.

Note. — It takes 20 men to load a ponton on its wagon.

The Advance-Guard Ponton Bridge.

The Advance-Guard Ponton Bridge — used in the United States Service is a modification of the Russian ponton bridge. Being intended to accompany light troops, and detached columns, its material and equipage have been designed with a view to combining utility with mobility.

The advance-guard ponton is commonly known as the canvas ponton, two kinds of which have been used in our service. The one which has best stood the test of service, and which deserves recognition on that account — having accompanied General Sherman from Chattanooga to the Sea — is the one selected for description.

The Bridge Material — carried in the train consists of: — First, — trestles, trestle balks, abutment sills, scoops, rack sticks, pickets, and buckets. Second, — ponton frames, ponton covers, short balks, chess, anchors, paddles, boat hooks, ponton boxes, cables, lashings, mallets, and scoop shovels.

The material comprised in the first category has already been described in the paper on the Reserve-Train Ponton Bridge (p. 40). That included in the second will now be described.

The Ponton Frame — consists of 2 folding side frames, 15 transoms, a binding rope, 2 rope braces, and a few flooring boards. Its several parts are joined by tenon and mortise, bound together by the binding rope which passes completely round the frame and is tightened by a rack stick, and braced by diagonal rope braces on the inside near the ends.

All the wood work, with the exception of the claws on the balks, and the blocks in the trestle caps, is of white pine.

The Side Frame — consists of 2 rails — an upper and a lower — 12 posts, 4 braces, and 2 hinges.

The Upper Rail — is 21 feet long, 3 inches wide, and 3 inches deep. It is divided at the middle, the parts being hinged together by an iron hinge, the plates of which are each 12 inches long by 2 inches wide. The hinge is countersunk in the rail on the inside, and fastened by 6 screws in each plate.

The upper rail is mortised for 6 posts in each half, and at unequal intervals. The first, at the end, enters obliquely, at an angle equal to the bevel of the end of the ponton, the others enter at right angles to the rail. The distance from the end to the center of the second mortise is 1 foot 10 inches; from the center of the second to the center of the third, 1 foot 8 inches; from the third to the fourth, 2 feet; from the fourth to the fifth, 2 feet 4 inches; from the fifth to the sixth, 2 feet 3 inches; and from the sixth to the joint, 5 inches; making in all 10 feet 6 inches the length of one half of the rail. The other half is exactly like it.

The Lower Rail — is 18 feet 4 inches long, 3 inches wide, and 3 inches deep, hinged at the middle like the upper rail, except that the hinge is fastened on by rivets instead of screws. It is mortised for 6 posts in each half, one of which, the

end one, enters at an oblique angle as in the upper rail. The distance from the end to the middle of the second mortise is 6 inches; from the middle of the second to the middle of the third, 1 foot 8 inches; and the others as in the upper rail, making in all 9 feet 2 inches, which is the length of one half of the lower rail. The other half is exactly like it.

The Posts — are of 3-inch scantling. The upright posts are 1 foot 10 inches long, exclusive of the tenons at the ends which fit into the mortises in the rails. The oblique post is at the end, and unites the ends of the upper and lower side rails. There are 5 upright and 1 oblique post in each half of the side frame.

The Braces — are of 2″ x 3″ scantling. There are two braces in each half of the side frame — one in each of the two middle spaces of the half frame — as diagonals, extending from the lower to the upper corner of the space, the inclination towards the hinge.

The Transoms. — There are 4 bottom, 1 end, and 2 top transoms in each half of the ponton frame, making 14 transoms in all, besides a special transom, called the middle transom, which binds the ponton frame near the middle. The transoms unite the side frames together, thus constituting the skeleton ponton known as the ponton frame.

The Bottom Transoms — are 4 feet 10 inches, exclusive of the tenons, 4 inches wide and 2½ inches thick.

The End Transoms — are 5 feet 4 inches long, exclusive of the tenons, 10 inches wide, and 1½ inches thick. They fit into mortises in the oblique posts, and give shape to the ends of the ponton.

The Top Transoms — are 5 feet 4 inches long, 4 inches wide and 2½ inches thick. There are two top transoms in each half of the ponton frame, one at the end, and one 2 feet 6 inches from it. The second one is provided with a mooring becket at the middle.

The Middle Transom — is of 3″ x 3″ scantling, is 5 feet 4 inches long including the plates. The wooden part is 4 feet 10 inches long, and fits between the upper rails near the middle of the ponton frame. The plates are of iron, riveted to the upper side of the transom at the ends, and extending outwards 3 inches, where they bend downwards, at right-angles, grasping the outside of the upper rail. The middle transom is the principle brace of the ponton frame.

The Binding Rope — is a 3-inch manilla rope, which, passing through rings at the angles on the inside of the ponton frame above and below, and extending clear around the frame, is racked with a rack stick, and binds the frame together.

The Rope Braces — are that portion of the binding rope which crosses diagonally near the ends of the ponton frame, and are tightened by means of a rack stick at the point of intersection.

The Ponton Cover — is of strong cotton duck, double seamed, and made to fit the ponton frame. It has a double border 1½ inches wide. The eyelets are of metal.

The Short Balks — are of 4½ inch scantling, 22 feet long, with cleats of oak 29 feet 10 inches apart.

The Chess — are 11 feet long, 12 inches wide, and 1½ inches thick, with notches 18 inches long, and ¾ of an inch deep on both sides at the ends.

The Anchors — are 75 lb. kedge anchors.

The Paddles — are 8 feet long.

The Boat Hooks — are of the ordinary form, blunted so as not to injure the canvas.

The Ponton Box — is made to hold the ponton cover. It is 8 feet long, 2 feet 4 inches wide, and 18 inches deep, with strong rope handles at the ends. The lid is covered with canvas, overlapping 3 inches all round.

The Cables — are 30 fathoms long, and made of 3-inch manilla rope.

The Lashings — are of 1-inch manilla rope, 18 feet long, with a loop at one end.

The Mallets — are ordinary carpenter's mallet.s

The Scoop Shovels — are of galvanized iron.

Bridge Construction with the Advance-Guard Bridge Equipage.

Although bridges can be constructed with this equipage by any of the methods described for the Reserve Train Bridge, the practice is to adhere to the first method, namely construction by ponton.

Construction by Ponton — with the Advance-Guard Equipage is accomplished in exactly the same way as with the equipage of the Reserve-Train Bridge, except in the preliminaries, which are modified as follows : —

Preliminaries. — The material is unloaded and distributed as in the case of the Reserve-Train Bridge except as follows : —

The parts of the ponton frame are carried to some convenient place near the water, and then put together, lashed, racked, and turned, bottom up.

The ponton cover is taken from the box and drawn over the frame. The ponton is then turned right side up and launched, the flooring boards placed, the lashings of the cover secured, the equipment put on board, and the ponton is ready to be placed.

Note. — The ponton complete only weighs 510 lbs. and can be handled or carried easily by 8 men.

Dismantling. — The same as for the Reserve Train Bridge, with the necessary addition of uncovering, taking apart, and packing the ponton, which are simply the preliminary operations of putting it together, reversed.

The Train — consists of 4 ponton div sions, 1 tool wagon, and 1 travelling forge.

The Division — consists ot 8 ponton wagons, 2 chess wagons, and 2 trestle wagons.

The Wagons — are identical with the chess wagon of the Reserve-Train Equipage.

Loads.

The Ponton Wagon — carries 7 balks, 16 chess, 2 side frames, 1 cable, 1 anchor, 1 axe, and the ponton box containing, 1 ponton cover, 14 transoms, 5 paddles, 2 scoops, 2 mallets, 20 lashings, 2 boat hooks, 1 scoop shovel, and 8 rack sticks.

The Chess Wagon — carries 50 chess, and a box containing 2 spare ponton covers.

The Trestle Wagon — carries 14 balks, 1 trestle complete, 1 abutment sill, 1 coil of 3-inch and 1 of 1-inch manilla rope.

The Tool Wagon — carries the same load as the tool wagon of the Reserve Train Equipage.

The Forge is identical with Forge A, Ordnance Department.

Packing the Loads.

The Ponton Wagon — is packed by placing on the right, in the first course, 7 balks, the dowels on the front bolster fitting into the corresponding holes in the ends of the balks, and on the left, 8 chess on edge, their notches resting on the middle and rear bolsters. The 2 side frames are laid on the top of the balks, their lower sides resting against the chess. The wagon transoms are then laid in the upper notches of the chess. In the second course the 8 remaining chess are placed over those already packed, and the ponton box is set on the top of the side frames. The binders are now hooked on, the cable is coiled on the side frames in front of the ponton box, and the anchor slung under the side rails. The load is then lashed to the rings of the wagon, the lashings passing through the handles of the ponton box and rings of the side frames, and the axe is set in the sling on the rear axle.

The Chess Wagon — is packed with 30 chess on edge, in the first course, and 20 in the second, 10 of which are lashed to the right, and 10 to the left lashing rings. The box containing 2 spare ponton covers, rests on the front bolster in front of the chess, and is lashed to the front lashing rings. The load is then bound by hooking the binding chains.

The Trestle Wagon – carries, in the first course, 7 short balks and 2 trestle balks. In the second, 5 trestle balks, 1 abutment sill, and 1 trestle cap. In the third, 2 coils of rope, and 2 trestle legs. The bindings are then hooked on, and the load properly secured by lashings.

Personnel.

The number of trained pontoniers required for each division of the Advance-Guard Bridge Equipage is the same as for the Reserve-Train, namely, 5 non-commissioned officers and 56 privates. Commissioned officers, — 1 for one or two divisions, and 3 for a train.

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